Reconstructing the Iron Production Technologies of Western Uganda: reconciling archaeometallurgical and ethnoarchaeological approaches

Thesis submitted for

Doctorate of Philosophy (PhD)

Louise Elizabeth Iles

Institute of Archaeology

University College London

November 2010

Declaration

I, Louise Elizabeth Iles, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

Dated:

Abstract

The local production of iron was an important technology in eastern Africa up until the later twentieth century, when the use and reuse of imported iron overtook vernacular smelting industries and cemented their decline. Prior to this, the utilisation of local ores had produced iron for agricultural implements, household tools and weapons, serving the needs of many generations of farmers and herders across the region.

The smelters of western Uganda enjoyed a particularly esteemed reputation in recent history, especially among their neighbours in Buganda, yet prior to this research little was known about the technologies upon which this reputation was fostered. This thesis presents the results of six months of fieldwork in Uganda and subsequent archaeometallurgical analysis, which together revealed the complexities of smelting in western Uganda between the fourteenth and twentieth centuries.

Exploring this new archaeometallurgical dataset has indicated that some iron producers in Mwenge (a particularly iron-rich region of western Uganda) were selecting manganese-rich ores with which to supplement the iron ores in the smelt, imparting a tangible effect on the process and outcomes of these smelting episodes, hypothetically increasing the metal yield and improving operating parameters. Although such harnessing of beneficial manganese-rich minerals was an unexpected and unusual finding, technological reconstructions of these smelts highlighted several other interesting features, including the consistent use of grog temper in technical ceramics, the occasional use of banana pseudostems, and variations in furnace style. Combining these discoveries with existing ethnoarchaeological and ethnohistorical data, and building upon social approaches to iron technologies, it was possible to explore some of the possible reasons for this variation, adding colour and time-depth to the understanding of iron production within this region.

Table of contents

4 Applied Methodology

5 Technological Reconstructions: Mwenge, Proto-Kingdom Period

6 Technological Reconstructions: Mwenge, Kingdom Period

7 Technological Reconstructions: Wider Discussion and Interpretation

8 SUMMARY AND CONCLUSIONS

BIBLIOGRAPHY, APPENDICES

List of figures

(all figures are author's own unless otherwise stated in text)

List of tables

Acknowledgements

The Arts and Humanities Research Council funded this PhD, and additional assistance was received from the UCL Graduate School, the University of London Central Research Fund and the UCL Institute of Archaeology for fieldwork and conference costs. Radiocarbon dates were funded by the Oxford Radiocarbon Accelerator Dating Service. Thanks must go to the British Institute in Eastern Africa for their support, and for providing invaluable students in the field.

This research could not have gone ahead without permission from, and the support of several agencies in Uganda: the Uganda Museum in Kampala and its staff (especially Rose Nkaale and Dismas Ongwen), and the Uganda National Council for Science and Technology and the President's Office. Thanks must also go to those at the offices of the Prime Minister of the Bunyoro-Kitara Kingdom, and to the countless district and local officials who assisted the team and the project in the field.

Heartfelt thanks go to Charlotte Karungi and her family who welcomed me into their home, and provided me with a second family in Kampala. I am indebted to those who worked alongside me in Uganda for the entirety of the project: Elijah Kisembo (a most brilliant research assistant, multilinguist, negotiator and friend), Dismas Ongwen (without whom the project wouldn't have been the same) and Paulo Kabuye (for looking after camp, protecting us from the Ugandan wildlife and cattle, and for feeding us all). Huge thanks to those who joined the project for survey and excavation: André Ntagwabira, Ian Travers, Stephen Whitfield, Wilfred Ruhega, Sherri Amin and Nick Gestrich, as well as a brief appearance from Sarah Wolff. Thanks also for accommodation in Kampala to the Backpackers Hostel, and for fun and friendship from the girls behind the bar (Pinky, Fionah and Grace). I am also grateful to Badru, for advice with vehicle purchase and negotiating the Kampala bureaucracy.

In London, the support, encouragement and guidance of my supervisors Dr. Andrew Reid and Dr. Marcos Martinón-Torres has been unfailing, and their continual faith in me has always been able to give me a boost when most needed.

I am thankful to so many others who have helped me over the years, including Paul Lane, Thilo Rehren, Dave Killick and Ceri Ashley, from whom I have learnt so much. In particular for this project, I am indebted to Terry Childs, Pete Robertshaw and John Sutton for their knowledgeable advice, comments and suggestions, and to Simon Groom and Kevin Reeves for their guidance in the lab. A mention must also go to Andy Garrard for seeing enough potential in me during my interview to persuade UCL to let me on the archaeology undergraduate degree course without the necessary qualifications…

To amazing friends at the institute and in the wider world over these past years – Jane, Gabe, Nick, Ceri, John, Kat, Meredith, Tobi, Anna, Steve, Claire, Kristina, Vicky, Alice, Jenny, Tessa, Hilary, James, Stu, Sherri, Anastasia, Miljana, Claudia, Niki, Amara, Liza, Lauren, Jason, Maria, Karen, Dan, Merlyn, Rosie, Andrew, Paul, Brendan, Mike – great times have been had in the office and in many a Bloomsbury pub. To Drs. Jane Humphris and John Giblin, who have been here through it all, who have been the greatest friends, and who I have shared the best times with across eastern Africa and at home – a huge thank you.

Finally, to my family, James, CCAME, and especially my parents – Elizabeth and Sid – the greatest thanks for supporting me in this crazy endeavour and helping me achieve this big blue book.

CHAPTER 1

WESTERN UGANDA AND THE ROLE OF IRON METALLURGY

The adoption and adaptation of new technologies is a significant factor in determining how societies respond to challenges, internal and external, past and present. We need look no further than our day-to-day lives to see that we are continually required to negotiate previously unintelligible technological landscapes. However, this confrontation of change is not only relevant in the modern era; our predecessors' acceptance or rejection of past innovations has influenced much of where we find ourselves today. Understanding these processes of innovation and technological uptake can be a key feature in allowing us to understand the development of past social systems.

Iron production was one of the most prominent transformative processes harnessed by much (though significantly not all) of the pre-industrial world, driving political, social, economic and environmental change from as early as the second millennium BC. The impact made by iron lay in its power both to create and destroy. It has often been credited with enabling the clearance of dense forest and facilitating the expansion of agriculture, thereby encouraging increased sedentism and the growth of urban centres. Yet it is also associated with the production of strong weapons that were to feed territorial disputes and battles, shaping political systems and precipitating the rise of empires. This duality fascinated those who worked with it and those who depended upon it, and accordingly ironworking was incorporated within many early mythologies around the globe.

Each transition to the complex technology of iron production was undoubtedly the result of an intricate sequence of events, taking place at a particular time and in a particular place. And as much as iron production constitutes a chemical and physical transformation, there are many ways in which its material requirements can be met. Above all, technology is a social process, where smelters and smiths – with their wealth of individual knowledge and experience – operate within constraints and expectations specific to the communities within which they live and work. Iron technologies are adapted and transformed across space and time in connection with changing environments and cultural contexts. The end result is a vast range of variation in the iron technologies that have been developed, including large wind-powered smelting furnaces in Sri Lanka (Juleff 1996, 2009), small Romano-British shaft furnaces (e.g. Jackson *et al.* 1988), ceramic-hungry smelts in Mafa, Cameroon (David *et al.* 1989) and crucible steel production in southern India (Srinivasan 1994). Yet, whilst recognising this diversity, and recognising the significance of iron as a key innovation, "details of its evolution are poorly understood" (Charlton *et al.* 2010: 352): there is much still to discover about how this important technology took hold and was transformed within many cultures across the world.

In light of these thoughts, the research presented here will discuss the precolonial iron production technologies of an area of western Uganda called Mwenge – a region noted for its prolific ironworking, where archaeological resources are complemented by detailed oral histories and ethnographic records. Here, iron production is thought to have held a prominent place in the early acquisition of power and the development of the later kingdoms that dominated the region in the second millennium AD.

PART ONE: CONTEXT, AIMS AND OUTLINE OF THE THESIS

In a broad sense, this research is concerned with reconstructing the social and technical aspects of the iron production technologies practiced in Mwenge, western Uganda in the second millennium AD. Western Uganda has a complex history; one that is pieced together through a variety of disparate and often conflicting sources (to be discussed in Chapter 2). Yet a constant thread through all accounts is the importance of iron production to this area, in the period prior to colonial activity.

In recent years at the UCL Institute of Archaeology, researchers have investigated variability within the iron producing technologies of eastern and southern Africa on a number of levels: Chirikure (2002, 2005; Chirikure and Rehren 2006) studied the iron producers of a region of precolonial Zimbabwe on a very general scale, embracing several larger population groups within that study, whereas Humphris and myself (Humphris 2004; Iles 2004, forthcoming; Humphris *et al.* 2009; Humphris and Iles, forthcoming) considered iron producers in two areas of a smaller, more defined political region – the precolonial kingdom of Buganda, Uganda – finding that past iron technologies varied between the social groups that existed within that kingdom; both regions revealed a level of variation that exceeded expectations. The research presented here joins recent work by Humphris in Rwanda (2010) to take the resolution of those studies one step further, by examining technological variation (and therefore, by inference, sociocultural diversity) within a single, defined community or locale – in this case Mwenge – that was renowned for its skilled production of iron, and which operated (at least in more recent centuries) within the confines of a larger political unit that relied heavily on such iron production for its economic and military success.

The region's complex political past has led to a proliferation of names that apply to the geographical area under study. Mwenge is at the moment the name of a county in Kyenjojo district (*cf.* Figures 1.1, 2.2 and 4.2); this defines the area in a geographical sense, but is inadequate to describe the historical affiliations of the place and people. At different times, Mwenge has been part of the Bunyoro kingdom, the Toro kingdom, and has had a succession of powerful and challenging chiefs of its own, one of which is reputed to have tried to make Mwenge into a kingdom in its own right (Ingham 1975; Uzoigwe 1982). And this is only within the last few centuries. Prior to this, Mwenge – along with much of western Uganda – is considered to have been part of a wider regional entity known as Kitara: "the region roughly centred on Mubende and encompassing much of what was regarded as Bunyoro, Toro, Nkore" (Robertshaw *et al.* 2004: 536), as well as including parts of east and west Buganda, Buddu and parts of what is now the Democratic Republic of the Congo (Gorju 1920; Uzoigwe 1972; Buchanan 1978; Tantala 1989; Robertshaw *et al.* 2004).

What this terminology means politically, in terms of the influence and control of this Kitara 'empire' has been difficult to establish, although it may mean only the existence of a "cultural region with elements of a shared history of considerable depth"; certainly, this expansive region has striking *linguistic* continuity (Sutton 1993: 40), with a mutually-intelligible language spanning from Murchison Falls in the north to Nkore in the south (Maddox 1902). Consigned as an 'archaic' term from around the nineteenth century, the concept of 'Kitara' was revived in the 1930s in order to give more historical weight to the much-reduced Bunyoro kingdom (*cf.* Chapter 2), which eventually led to it being renamed Bunyoro-Kitara (Tantala 1989: x).

For the sake of simplicity, and to avoid the political connotations that accompany some of the terminology of place within the region, I have chosen to refer primarily to 'western Uganda' (rather than 'Kitara' or 'Bunyoro-Kitara') to denote the wider area covered by this research, with the focus of the study resting on the geographical location of Mwenge (Figure 1.1). This avoids dealing with potentially confusing layers of social identity that can arise when more loaded terms of political affiliation – with their propensity to change – are used[1]. Figure 1.1 shows just how complex social identity is within the region under question.

[1] For example, Childs' ethnoarchaeological work (undertaken in Mwenge) refers explicitly to 'Toro' smelting, when others might refer to it as 'Nyoro'.

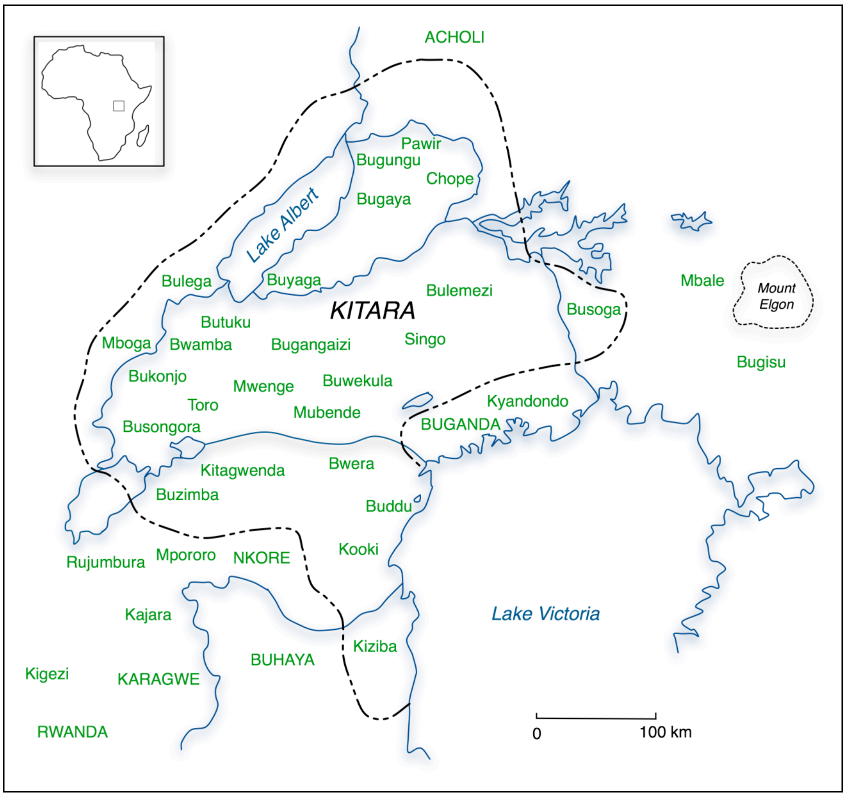


Figure 1.1 Map of maximum posited extent of 'Kitara', also showing some neighbouring polities. Redrawn after Buchanan (1979) and Ingham (1975)

This region – western Uganda, and particularly Mwenge – is the focal point for a relatively extensive range (although not volume) of multi-disciplinary information relevant to archaeological investigation. Not only are there rich ethnohistorical resources for the region, detailed studies of oral histories have also been undertaken, along with several excavations of archaeological sites, ethnoarchaeological examinations of local iron production, and sediment-based palaeoenvironmental studies (Robertshaw *et al.* 2004, *cf.* Chapter 2). Several formal and informal archaeological surveys hinted at the rich archaeometallurgical remains to be found there. Yet the archaeological study of its iron metallurgy has until now been somewhat neglected (Tosh 1970: 106; Robertshaw 1994: 128). This research will begin to address this imbalance, whilst also contributing to the growing body of archaeometallurgical knowledge of the wider region. It will draw upon recent, holistic approaches tailored to African contexts to try to understand production from both technical and social perspectives, recognising the embedded nature of such technologies (to be discussed in Chapter 3). The potential of such investigations has already been clearly demonstrated (e.g. Schmidt 1997).

Within this context, this PhD research set out to examine several facets of the iron production technologies of the area within a defined set of research questions. The central theme to this research was to be an examination of the variation or continuity present in the iron technologies of Mwenge, as expressed within the archaeometallurgical record. The ethnohistorical work of Buchanan proposed the existence of a 'pattern' of iron production typical to the Mwenge area that pre-dated and survived what she calls the "more specialized development of the 19th century … [when] the Babito encouraged greater production and specialization" (Buchanan 1979: 104; *cf.* Chapters 2). The premise of this research is to explore whether this continuity in technology is reinforced or challenged by the archaeological record.

With this in mind, the three main questions to be examined were framed as follows:

- *How is variation expressed across and within the iron technologies?*

What technical variation is there within and between the excavated sites, and how can this be related to social, economic, technical or environmental factors? This will include a consideration of furnace shape, size and design; mechanisms for slag removal; furnace charge; the capabilities of the technical ceramics; the operation of the furnace and so on. How might these variables have affected the outcome of the smelts at each site and why were these methods chosen? How tightly regulated were these technologies? Was a certain recipe and methodology adhered to, or did individual groups of smelters follow discrete formulas when they smelted?

Also, what evidence is there, if any, for the use of materials with known ritual applications (e.g. the use of white kaolinitic clays as seen in the smelting technologies of parts of neighbouring Buganda), or for other ritual or magical elements associated with the smelt? This could include such possibilities as the burial of items under furnaces, the use of specific meaningful materials, or the identification of symbolism on material remains (e.g. furnace walls, bellows) and so on. If present, what can these tell us about the socio-cultural pressures and belief-systems acting upon the smelters?

- *What can variation tell us about how iron production was organised within Mwenge?*

What can we say about the nature and level of control that was exerted over what is known to have been an economically and socially significant industry? We know that in neighbouring kingdoms, such as Nyiginya (in present-day Rwanda) and Buganda, there appears to be variation occurring in precolonial iron production technologies on a relatively local level (Célis 1987; Iles 2004; Humphris 2004, 2010). Humphris *et al.* (2009) argue that in precolonial Buganda, a centralised demand and stimulus for iron required adaptation on the part of local smelters, prompting variation: iron production in the Great Lakes has so far *not* been shown to be standardised.

By examining the situation in Mwenge, as a significant centre of iron production in western Uganda, the extent to which the iron industries were controlled may be revealed. Were iron producers able to work to their own smelting recipes, adding their own innovations? Or did 'tradition' (or other constraints, such as efficiency, political control etc.) encourage the maintenance of certain dominant styles of smelting? Did the identity of a group of smelters have a tangible bearing on the type of technological process they chose to implement? What role did the acquisition of knowledge play in the development of iron smelting styles in the region?

- *What relationship (if any) is there between the archaeometallurgical record, and the ethnohistorical and ethnoarchaeological datasets?*

The rich ethnohistorical and ethnoarchaeological records from western Uganda, and specifically Mwenge, offer an exciting opportunity to compare this data with the archaeometallurgical data generated through this research. Are there any common features between the archaeological and ethnohistorical records? The application of ethnoarchaeological and ethnohistorical resources to archaeological data is widespread (*cf.* David and Kramer 2001; Iles and Childs, forthcoming), yet it can be a troublesome approach (*cf.* Chapter 2). Might the new material from Mwenge be able to contribute to the wider debate concerning the use of ethnographic and ethnohistorical data in archaeological contexts?

Together, these questions will allow me to explore the wider significance of iron production within western Uganda, and discuss the relationships of these industries and their craft specialists to the political and social structures within which they operated, as well as placing the results within their wider regional context. It is hoped that a comparatively good understanding of the above questions can be achieved due to the relatively large number of sites excavated, and the localised geographical area that they cover.

This research builds upon a solid and growing body of work regarding the iron technologies of sub-Saharan Africa, the archaeology of Great Lakes Africa and social theories of technology, whilst utilising a proven method that integrates archaeological and archaeometallurgical approaches. Within this and the following three chapters, this background knowledge will be described and discussed in order to contextualise the newly generated data, whilst providing further justification for the research. What remains of Chapter 1 outlines the study of iron production, set within a broad overview of our archaeological knowledge of iron on a global scale. Chapter 2 introduces the geographical region of study to be examined, the resources that are available, and the historical contexts for the research. Chapter 3 presents the theoretical framework within which this research was conceived and undertaken; Chapter 4 describes how the research was, in fact, carried out. In Chapters 5 and 6, the new data that has been generated – organised chronologically – is presented and examined, followed by a detailed interpretation and discussion of these results in Chapter 7. The final chapter, Chapter 8, integrates the new data and the background contexts to discuss the questions posed originally within this first chapter, and to suggest avenues for future research.

PART TWO: UNDERSTANDING IRON PRODUCTION

Winning iron from an ore is a complex process, and one that is difficult to master. Within it are brought together a range of technologies that have to mesh together as a complete technological system to result in a successful outcome. A viable ore has to be procured, charcoal has to be prepared, furnaces have to be constructed, social obligations have to be fulfilled; each is as critical to the outcome as the next.

Like all material technologies, iron production is governed by two parameters: the scientific constraints and requirements of the chemical and physical worlds; and the social realms within which the technology operates including the economic markets that it feeds. Technology has to (or at least has to *appear* to) operate within certain frameworks and rules that are deemed acceptable to the public and governing systems at large. These frameworks and rules (e.g. whether children or women should be allowed to (or required to) work) are formed by those groups' wider worldviews, and are subject to flex and reform in quite significant fashion. These worldviews, and changes therein, can leave their mark on the technological methodologies that are implemented and the products that are manufactured, allowing archaeologists a glimpse into past social realms through the examination of material culture. These concepts will be introduced more fully in Chapter 3; here instead will be a brief introduction as to the chemical and physical requirements of iron production and the development of this technology across the world.

TECHNICAL PARAMETERS

Bloomery smelting is the process of iron production most commonly encountered in the archaeological record (Bachmann 1982: 30), and it was practiced across much of precolonial sub-Saharan Africa (Miller and van der Merwe 1994). The principals of bloomery iron smelting are generally well understood, and have been discussed at length elsewhere (e.g. Rostoker and Bronson 1990; Pleiner 2000; Joosten 2004; Rehren *et al.* 2007). As such, only a broad overview of the technology will be presented here.

Iron smelting comprises, in a basic sense, two fundamental chemical and physical events that separate iron metal from a host rock. On the one hand, iron oxides contained within an iron ore have to be *physically* removed from the surrounding rock (or gangue) matrix, which is generally composed of compounds such as silica, lime, potash or alumina (Rostoker and Bronson 1990: 81; Joosten 2004: 7). Equally as important, these iron oxides must be *chemically* reduced to elemental iron (Fe), by removing the oxygen atoms that are combined with the iron in its oxidised state.

Bloomery smelting operates at a temperature below the melting point of iron (1540°C), and instead operates at a temperature at which the gangue materials will melt and separate from the iron oxides, a situation that generally occurs at around 1200°C but which is dependent on the composition of the gangue (Joosten 2004: 9). The particles of metallic iron are thought to remain solid throughout.

For a successful smelt, three minimum requirements have to be met: there needs to be a high temperature (to melt the gangue minerals and facilitate their separation from the iron oxides), a means to physically separate this molten gangue from the residual iron, and a reducing environment (to separate the oxygen and iron atoms). The smelting operation takes place within a furnace that is specially designed to meet these criteria. Oxygen (in air), which is required to facilitate combustion, is introduced to the furnace in a controlled fashion, either through forced draft using bellows and tuyères, or by natural draft taking advantage of prevailing winds or utilising the chimney effect i.e. the updraft movement of hot air. The introduced air enables the fuel, often charcoal, to burn, producing carbon monoxide through the incomplete combustion of the carbon-rich fuel. The oxygen-hungry carbon monoxide reacts with the iron oxide, combining with its oxygen atoms to form carbon dioxide and reducing the iron oxide to the successively lower oxides of magnetite and wüstite, which are in turn eventually reduced to metallic iron (Joosten 2004: 8):

$C + O_2 \rightarrow CO_2$	
$CO_2 + C \rightarrow 2CO$	(charcoal combustion)
$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$	(haematite reducing to magnetite)
$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$	(magnetite reducing to wüstite)
$FeO + CO \rightarrow Fe + CO_2$	(wüstite reducing to metallic iron)

In a shaft furnace, the ore and charcoal charge move down within the furnace as the smelt progresses, exposing the ore to differing zones of temperature and atmosphere, and facilitating different stages of the reduction process (*cf.* Pleiner 2000: 134). The iron initially begins to form quite high in the furnace, above the main combustion zone. The forming liquid slag encases the solid iron particles and protects them from reoxidising as they move down within the furnace, providing a medium within which these iron particles can move and gather together, allowing them to gradually combine into a spongy mass of iron bloom and slag in the hottest part of the furnace, immediately beneath the tuyère inlets (Joosten 2004: 9). This protective slag coating also limits the diffusion of carbon into the forming bloom, avoiding the inadvertent production of brittle cast iron (Hedges and Salter 1979), and provides a medium within which the solid iron particles can move and gather together.

The end result is a solid and malleable 'bloom' of iron metal, and a waste product of primarily molten gangue: a "heterogeneous silicate complex" termed slag (Pleiner 2000: 131, 251), that also incorporates a large proportion of unreduced iron oxide (sacrificed in order to allow a molten slag to form) as well as varying proportions of technical ceramics, fuel ash and any additional fluxes that melted into the smelt. The impure bloom of iron initially contains a considerable amount of slag and charcoal inclusions. If this material is to be forged into an iron object, it first needs to be consolidated by reduction smithing. This involves heating the bloom to a white heat in order for the slag to re-melt, and hammering it to expel the trapped slag, air and other inclusions (Rostoker and Bronson 1990: 94). Once this has taken place, the iron will have lost much of its brittleness and can be used.

The furnace body, in addition to containing the reaction process described above, must also provide a way to physically separate the molten slag from the iron bloom. In the case of pit furnaces, the slag drips into a pit dug beneath the furnace, which is often packed with plant material in order to provide a support for the charge. Alternatively, the slag can be periodically drained out into a pit dug *next* to the furnace (termed slag-tapping).

The resultant slag is a valuable tool for archaeometallurgists, and importantly, it is one that tends to be well preserved archaeologically. Encased *within* it is information regarding the raw materials that were introduced into the system (i.e. the compositions and contributions of the ore charge, fuel, fluxes and technical ceramics), as well as data regarding how they were processed and how the slag formed (i.e. temperatures, cooling rates, atmospheres, and consistency thereof). Encased *upon* and *throughout* it is information regarding the structure and operation of the furnace (e.g. slag tapping vs. non-slag tapping, further information regarding how the slag formed), and the use of plant materials (*cf.* Mikkelsen 1997, 2003; Iles 2004).

This research is based on the premise that these data can be accessed through the macroscopic, microscopic and chemical analysis of slag blocks in conjunction with other material remains from a smelting event. Through this, past smelting episodes can be reconstructed, allowing inferences to be made about the reasons as to *why* certain technological approaches were chosen in each instance; as much as there are technical constraints as outlined here, there is always room for cultural choice and variability.

THE HISTORY OF IRON METALLURGY

The earliest iron objects that have so far been found have tended to occur around the Middle and Near East. A limited number of objects dating from as early as the fifth millennium BC have been excavated from sites in Iraq, Iran and Egypt. The great majority of these artefacts are made of iron with a high nickel content (up to 7.5%), which makes it likely that these examples are made from meteoritic iron – what the Egyptians referred to as 'iron of heaven' – directly forgeable (although difficult to work) and presumably an exotic material (Waldbaum 1999: 30). Through the third millennium, objects gradually begin to appear – in Anatolia and Mesopotamia – that seem to have been crafted from smelted iron (Pleiner 2000: 7).

Linguistic evidence from the same region adds to the evidence of a growing role of iron in society from the late third and early second millennia BC. Iron objects are found often in burial contexts, such as the fourteenth century BC tomb of Tutankhamen, in which a ceremonial iron headrest was found among the burial goods laid to rest with the king (Pleiner 2000: 10). It might be said that at this time, from the inception of the use of iron in this area until at least the end of the second millennium BC, "iron was an extremely precious metal" (Pleiner 2000: 11): it seems that iron had not yet become a widely used utilitarian material.

In this region of the world, where much of the early evidence for iron is concentrated, bronze metallurgy was firmly in place before the new technology of iron production developed. Iron is often lauded as a metal vastly superior to bronze, yet this is not likely to have been immediately correct. Early bloomery iron, before techniques such as carburisation or quenching and tempering or cold hammering had been developed, would instead have been far inferior (at least in terms of hardness) to the existing bronze technologies (Waldbaum 1999). This is relevant when considering the adoption of metal technologies and their development. In other areas, however, where prior metal technologies were not in operation (as, for example, in much of sub-Saharan Africa), the development of iron technologies may have made more of an immediate impact. However, despite this early, unfavourable comparison with bronze, iron had one major advantage – the ubiquity of its ores.

It is widely considered that the invention of iron technology developed as a by-product of existing copper smelting technologies. Iron minerals such as haematite or limonite, when added to sulphidic copper ores, improve copper yield and encourage the production of slag (Pleiner 2000: 12). It is posited that using iron minerals as a flux resulted in the accidental (and fortuitous) discovery of the smelting of iron ores (although this has more recently been called into question, *cf.* Merkel and Barrett 2000). An early development of iron production is likely to have occurred in the region centred around Anatolia and Mesopotamia; from this region, it is believed by many (e.g. Tylecote 1975; Pleiner 2000) that the technology dispersed throughout the rest of the Old World. Certainly, in other areas of the world, iron production technology was not adopted (or developed) until considerably later, not reaching the Americas until the sixteenth century. India and China see an increase in the number of iron objects from the mid first millennium BC, with Indian steel – "famous in the Roman world", and later famous as Wootz steel – produced from the first millennium AD (Pleiner 2000: 16-17).

However, there have been several arguments for independent inventions of iron technology around the globe, in India (Chakrabarti 1976), China (*cf.* Wagner 1999), and Africa (*cf.* Alpern 2005), although evidence for these troublesome, if tantalising, questions of origins is notoriously difficult to generate. Moving immediately to the topic of indigenous origins of iron production in Africa, several early dates for iron smelting furnaces, both in western and eastern Africa, have led to suggestions that sub-Saharan Africa not only acquired iron technology independently, but "skipped the Bronze Age entirely", making the transition to iron directly from stone (van der Merwe 1980: 497).

Until the 1960s, the bloomery iron technologies seen in sub-Saharan Africa were thought to have derived from one of two routes: either from the region of Meroë, on the Upper Nile in Sudan, where large-scale iron smelting produced an estimated 5000 tonnes of bloomery iron (Rehren 2001) between 300 BC and 350 AD; or from Carthage in north Africa, with knowledge of iron smelting transported across the desert by Berbers (e.g. Tylecote 1975). Yet the foundations for these beliefs were based primarily on an *assumption* of technological diffusion rather than evidence for it. With the growth of radiocarbon dating in the later twentieth century, these assumptions were called into question and forced to defend themselves (*cf.* Trigger 1969).

As well as early dates for iron smelting in western Africa from approximately the first half of the first millennium BC (*cf.* Holl 2009), there also began to appear early dates from the southern Great Lakes – Rwanda, Burundi and northwest Tanzania. Here, there was an intriguing collection of radiocarbon dates that spanned between 4000 and 1600 BC (van Grunderbeek *et al.* 1982, 2001; Schmidt and Childs 1985; Schmidt 1997). If these were correct, this would place those iron smelting events at an earlier point of history than the extensive smelting at Meroë. The furnaces themselves were also very different from those seen far to the north. In contrast to the slag-tapping furnaces at Meroë, which are similar to those of Roman-influenced Egypt (Woodhouse 1998), the early Great Lakes furnaces are all slag-pit furnaces, with conical shafts often constructed using decorated bricks (*cf.* Killick 2009). Might this distinctive technology indicate an indigenous invention of iron smelting in this region?

In more recent years, the earliest of these dates have been challenged, with the very real possibility that they are based on radiocarbon dates from charcoal found in furnaces but generated from wood burned originally in old forest fires – the 'old wood' problem. What remains are a number of secure dates from a more limited, but still very early, range – 800 to 400 BC (coinciding, unfortunately, with a plateau in the radiocarbon calibration curve) – dates which are in a comparable range with those from western Africa and from Meroë (Killick 2009), thereby diminishing their challenge to the diffusion theories.

However, archaeology as a methodology will always struggle to definitively prove an 'earliest' event; even improvements in the accuracy and precision of dating techniques may contribute only a finite amount to these discussions. What might be more relevant in the long term are studies that seek to isolate and discuss small scale variation. By refining our understanding of how technologies change, as people and/or ideas move into different cultural and environmental landscapes, we will be able to return to the big questions of origins with a greater knowledge of the intricacies of technological transmission (*cf.* for example Roberts *et al.* 2009). What may prove more fruitful, as shall be discussed in Chapter 3, is a heavier focus on questions regarding the role and impact of iron production within local histories as opposed to searching for solutions to broader global or regional narratives.

CHAPTER 2

ARCHAEOLOGICAL AND HISTORICAL CONTEXTS: SOCIETY AND IRON IN THE GREAT LAKES AND WESTERN UGANDA

The African 'Great Lakes' provides the background for the archaeological story told through this research. A term coined by nineteenth century western explorers in search of the source of the Nile, it reflects their preoccupation with the watercourses and inland seas that punctuated the region (*cf.* Chrétien 2003: 22-23). Nevertheless, it is a term that remains fitting to summarise a landscape of elevated land surrounded by lakes and mountains that trap rainfall and maintain a lush, cool environment, in stark contrast to the deserts to the north or forests to the west (Chrétien 2003: 24).

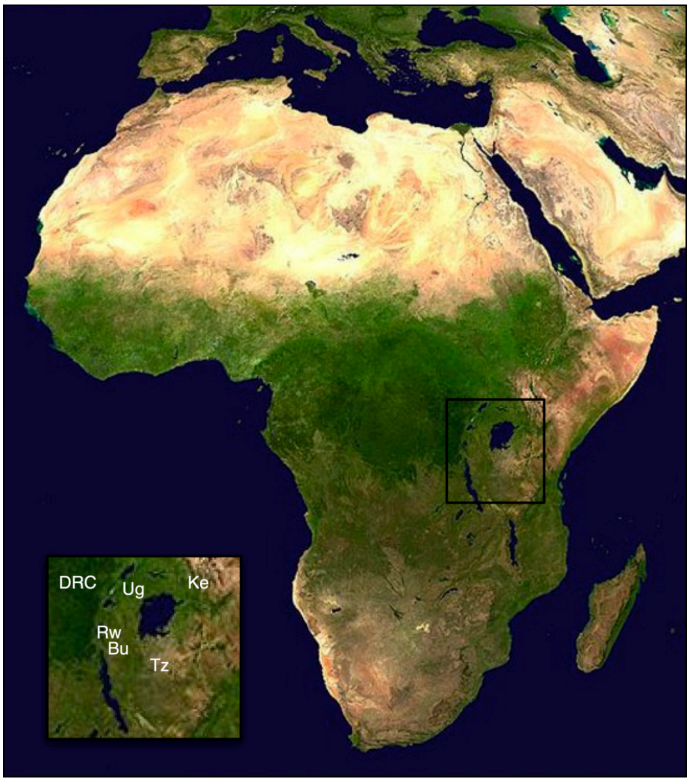


Figure 2.1 The Great Lakes region of Africa (Ug, Uganda; Ke, Kenya; Tz, Tanzania; Rw, Rwanda; Bu, Burundi; DRC, Democratic Republic of the Congo)

The region encompasses parts of what are now the countries of Uganda, Kenya, Tanzania, Rwanda, Burundi and the Democratic Republic of Congo (DRC, *cf.* Figure 2.1), whose borders were drawn up at the end of the nineteenth century at the culmination of the 'Scramble for Africa'. Yet these modern boundaries mask the dynamic network of kingdoms – connected not only by land, but by rivers and lakes, and shared cultural and linguistic histories – that dominated this region prior to the colonial division of the land (*cf.* Sutton 1993; Schoenbrun 1998; Kusimba and Kusimba 2005; Ashley 2005, 2010). Rich in resources and environmental diversity, this area provided early explorers with an "enchanting spectacle of banana gardens, fields of cereal crops and vegetables, and cattle herds" embedded within "centralized powers, social hierarchies, sacred polities, and ties of dependence" that fascinated travellers (Chrétien 2003: 24, 26). Early interest in the Great Lakes has persisted in the dense volume of scholarly research dedicated to it: linguistic, political, anthropological, environmental, and, most importantly for this research, metallurgical.

As mentioned in the previous chapter, the Great Lakes region has been a prominent focal point for discussions about early iron production in Africa, as well as investigations of later kingdom-related iron production industries. However, the focus of the research contained within this thesis rests upon a small geographical area in what is now Uganda that has, as yet, been much less extensively studied. This chapter provides an introduction to what is currently known about the events that shaped the social, environmental and political histories of this part of precolonial Uganda.

Broadly framed within the context of the wider territory of Kitara and the traditions of the later kingdoms of Bunyoro and Toro, this research examines iron production within one of the core regions of early western Uganda: Mwenge (Doyle 2000: 17). Mwenge is reputed to have been one of the most prolific iron producing regions of western Uganda (Buchanan 1974a: 39), and its boundaries remain preserved as a sub-county in Kyenjojo district. Although western Uganda as a whole has a complex and ambiguous history – this small part of it notwithstanding – Mwenge remains an area with a strong identity: many informants that we talked to during survey identified themselves as Banyamwenge before they identified themselves as Banyoro or Batoro (see also Torelli 1973)[1]. The fact that many traced their ancestry to outside of Mwenge did not diminish this affiliation. The importance of Mwenge to the later kingdoms at least, is indicated by several historical assertions: Mwenge was where Banyoro *ababiito* (princes) and *ababiitokati* (princesses) were brought up, and where the 'purest' form of Rutara was reputedly spoken (Ingham 1975: 11; Uzoigwe 1979: 40). As will be detailed in Chapter 4, the modern boundary of the sub-county of Mwenge formed the basis for the survey of this research.

Data about Uganda's western provinces is not as extensive as for other areas of Uganda, or indeed, many other areas of the Great Lakes. Archaeological research has been especially limited; up to the point of this research fewer than ten sites had been comprehensively excavated in a region that covers approximately 30,000km^2 (Robertshaw 1999: 128). Historical reconstructions (based on locally-recorded traditions and early observations by foreign visitors, as well as modern historical research) have been more prevalent, although needless to say, many of the documents on which they are based are heavily influenced by the colonial and postcolonial contexts within which they were written. Finally, linguistic and palaeoenvironmental records are further resources which have been used to reconstruct the past here, as well as more recent ethnoarchaeological endeavours. These resources, their applications and their shortcomings, will be described in Part One below.

Testament to the complex nature of western Uganda's past and the current limitations of the available resources, a detailed understanding of the dynamic social and political structuring of the region through time has not yet been fully unravelled. Nevertheless, a summary and analysis of the existing data will be presented in Part Two of this chapter, brought together to describe what is known about the later histories of this part of western Uganda. Furthermore, in order to set the scene for the newly generated data that shall be presented in Chapters 5 and 6, specific attention will be paid to themes relevant to iron production in Part Three.

[1] Throughout the text *Bu*nyoro or Nyoro refers to things *of* the kingdom, *Lu*nyoro to the language and *Ba*nyoro to the people. These prefixes are also applicable to other kingdoms in the region (e.g. Buganda).

PART ONE: SOURCES

"Like a great many other parts of sub-Saharan Africa, and indeed of the world, the Great Lakes region… does not have a long documentary history. It does, however, have a long history."

(Stephens 2009: 206-207)

Like the wider Great Lakes region, the history of western Uganda is, at the moment, conveyed primarily through a (admittedly large and varied) number of court, clan and colonial voices (e.g. Fisher 1911; Roscoe 1915, 1923; Bikunya 1927; Nyakatura 1973 [1947]; Oliver 1955; Babiiha 1958; Beattie 1960, 1968, 1971; Dunbar 1965; Kiwanuka 1968a; Buchanan 1974a, 1979). Although problematic to interpret and troublesome to verify (*cf.* Vansina 1985; Tantala 1989), these accounts have painted a rich and unique picture of the dynamics of western Uganda and how the region developed and changed over time, long before archaeology began to tell a coherent story in the region. Neil Kodesh (talking specifically about Ganda history, although this could equally be applied in a Nyoro context) argues: "our earliest glimpses into the distant Ganda past appear in the form of clan histories", rather than court traditions (Kodesh 2008: 199-200). What's more, these resources speak to a wide and diverse audience, not only to academia, with clan histories playing a more inclusive role in the ongoing formation of an active Nyoro history.

It has been repeatedly noted (e.g. Buchanan 1974b; Tantala 1989; Chrétien 2003; Doyle 2006a) that strong parallels exist between the court and clan traditions of neighbouring Great Lakes kingdoms – Buganda, Bunyoro, Nkore, Toro and others. These traditions tell not only of a series of interconnected local histories but also of region-wide interactions and connections; communicated through tales of origin stories and mythologies, of important battles and territorial disputes and of royal dynastic lines and interregional relationships: the Great Lakes is revealed as "a vast cultural zone, crisscrossed by related beliefs" (Chrétien 2003: 100). Even so, although there is frequent corroboration between these histories, they require careful and delicate consideration before they can be incorporated into a general narrative of the region's past.

A significant caveat to begin with is that these sources were written down and effectively ossified at or after the point of colonial contact, and are (as are all primary sources to varying degrees) heavily influenced by the contexts that frame them, whether written by local dignitaries or foreign visitors. At this time of contact, it is relevant to state that the kingdom of Bunyoro was no longer as dominant a force in the region as it had been, having lost much of its territory and power to Buganda and other neighbouring kingdoms towards the end of the nineteenth century (Kiwanuka 1968b; Chrétien 2003). This contrasts strongly with the situation of their Ganda rivals, who were at "the zenith of their political power and influence" (Oliver 1955: 111). The nature of early colonial interactions within Uganda meant that British attitudes tended to discriminate favourably towards Buganda at the expense of Nyoro interests. The Banyoro were repeatedly portrayed as "backward, reactionary and intractable" (Doyle 2006a: 5), a reputation that stuck.

As a further consequence of this, only a few foreign-led expeditions ventured into the heart of Bunyoro, preferring instead to visit only the outer reaches of this 'uncivilised backwater' (Doyle 2000), and for considerably less time. The early twentieth century 'missionary anthropologist' John Roscoe (Ray 1991: 17), although sympathetic to Nyoro interests, spent only four months in Bunyoro (as compared to the many years he spent in Buganda), although this was much extended from the three weeks that he had originally planned (Deane 2007: 37). All these factors had a serious (and often negative) impact upon the ways in which the past histories of Bunyoro were subsequently represented.

The tone and content of Nyoro court histories were also affected by these circumstances, and attempted to impress upon the reader (or listener) an inflated perception of the status of the kingdom in the region (see Doyle 2006b for an extensive discussion of the effect of Bunyoro's recent political history on the construction of its historical narrative). King lists, satisfying a European rather than African fixation (Henige 1974, 1980; see also Tantala 1989 and Chrétien 2003 for further discussion of Nyoro kinglists), were constructed, fortified, and most would say extended (e.g. Wrigley 1996: 38-41), to emphasise Bunyoro's regal longevity in the region in a manner appreciable by the British: "Nyoro found solace in their newly reduced circumstances by emphasizing their history, an undertaking that also aimed to bolster their standing with the British" (Robertshaw and Taylor 2000: 2). As such, these court histories, with their potential inaccuracies, offer only a distorted picture of "a reality that is far more complex and fluid" (Chrétien 2003: 165).

These early intangible historical resources have in more recent years been complemented by a growing body of archaeology, linguistic analysis and environmental reconstruction. Although it is acknowledged that these forms of data generation are *also* heavily dependent on interpretation and analysis, and are not immune from prejudice and preconception, they have served to add independent and tangible evidence to the body of historical information. Yet these sources too have been affected by the political history of the region.

Colonialism and nationalism have greatly influenced research agendas across sub-Saharan Africa, and archaeology in the Great Lakes and western Uganda is no exception (Robertshaw 2003: 149; and *cf.* Chapter 3). Somewhat removed geographically from the evidence for early man found in the Rift Valley to the east (e.g. Leakey 1931), and despite some initial interest in the 'Stone Age' of Uganda (e.g. O'Brien 1939; van Riet Lowe 1952), early archaeology was primarily focused on generating evidence that would either support or refute historical interpretations of the past that had previously aroused colonial interest, most notably narratives regarding the mythologised Bacwesi (Robertshaw 1994: 105; Taylor *et al.* 2000; *cf.* Part Two) or invading populations of civilising 'Hamites' (Chrétien 2003). In western Uganda, research tended to focus upon the excavation of large, monumental earthworks, such as those at Bigo and Ntusi, in order to satisfy these agendas (Robertshaw 1991a).

After a hiatus in research output due to regional political unrest in the 1960s and 1970s, the volume of archaeology undertaken in western Uganda increased in the 1980s and 1990s, encouraged by a large-scale, targeted Great Lakes project instigated by the British Institute in Eastern Africa (Sutton 1993). The change in emphasis was subtle but important; although research remained focused primarily on large earthworks sites, "archaeological interpretation was given precedence over historical reconstructions" (Robertshaw 1994: 105). The deeply stratified salt-production site of Kibiro, in the north of Bunyoro was also investigated (Connah 1996), illustrating an increasing interest in sites with a technological emphasis.

A further significant development was the undertaking of extensive, systematic surveys (in Bwera, Rakai, Mubende, Kibale, Mwenge and Hoima) to examine site location and settlement patterns (Reid 1990, 1991; Robertshaw 1991b, 1994; Connah 1996; MacLean 1996), bolstering the shift away from a focus on large sites towards a more regional perspective. Prior to this, sites had been located through chance or through communication with local informants, which inevitably favoured the discovery and investigation of larger and/or more historically prominent sites. Basic ceramic chronologies also began to be developed from this growing body of data (Robertshaw 1994; Connah 1996), although a well defined, high resolution chronological seriation of pottery is currently lacking due to the small sample sizes of pottery and the lack of absolute dates to anchor this seriation to (Robertshaw 1994). Ultimately, archaeological research has remained comparatively scant and sparsely situated across this expansive and socially complex landscape. Even so, archaeology has played a notable role in the past few decades, being used not only to support and purportedly verify historical reconstructions (*cf.* Schmidt 1990), but also in setting the agenda for future research (Robertshaw 1994: 107).

Critical examinations of oral histories and oral traditions (Buchanan 1974a; Tantala 1989), historical linguistics (Schoenbrun 1993a, 1993b, 1998), ethnoarchaeology (Childs 1998a, 1998b, 1999, 2000), anthropology, and environmental research – historical, palaeoclimatic and palaeoecological – (Taylor and Marchant 1994/1995; Jolly *et al.* 1997; Doyle 1998; Marchant and Taylor 1998; Taylor *et al.* 1999; Lejju *et al.* 2003; Lejju 2009) also grew in range and scope during this time, and have allowed for a more thorough picture of past life in western Uganda to be built. Nevertheless, these resources also have their problems. Oral histories and traditions and ethnoarchaeology are subject to issues of memory, value-laden agendas, relationships between informant and researcher and so on (*cf.* Iles and Childs, forthcoming).

Linguistic histories are surrounded by debates as to the validity of vocabulary reconstructions, relative dating and the controversial use of glottochronology (*cf.* Ehret 2000; Renfrew 2000; Crowley and Bowern 2009). Environmental reconstructions are dogged by difficulties in attributing cause and effect to patterns of vegetation change to infer human-environment inter-relationships, as well as accounting for the geographical distance between the sites used to generate palaeo-environmental samples and relevant archaeological sites (Stager *et al.* 1997; Robertshaw and Taylor 2000; Taylor *et al.* 2000; Lejju *et al.* 2003).

Despite the limitations of the currently available data, a picture of western Uganda's history can be pieced together from these sources, although this picture is sure to flex and change as more research is undertaken and more data and analysis becomes available. Several important syntheses (Sutton 1993; Schoenbrun 1998; Robertshaw and Taylor 2000; Taylor and Robertshaw 2001; Chrétien 2003; Robertshaw *et al.* 2004; Robertshaw 2010) have critically drawn together the existing range of information to offer a more developed and structured glimpse into the past interactions and dynamics that shaped modern-day western Uganda and the Great Lakes as a whole. Many gaps in our knowledge remain to be filled. Nevertheless, a brief 'sketch' of this history is outlined below, to provide context to the archaeometallurgical data that will be presented later in this thesis. Sites, regions and rivers and lakes mentioned in this chapter are illustrated below in Figure 2.2.

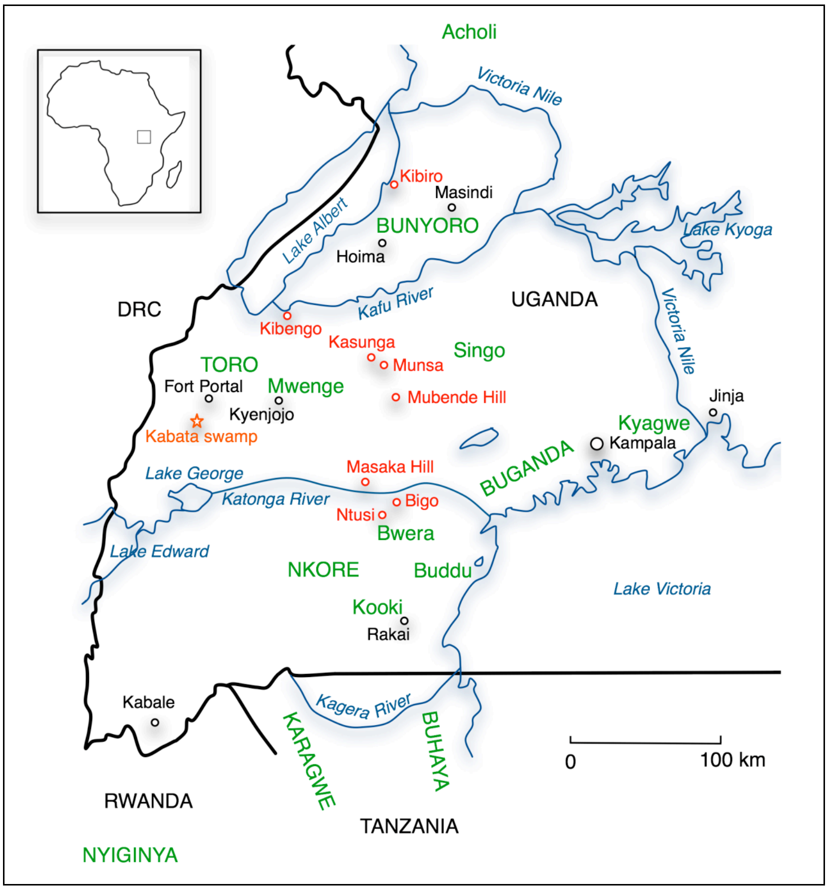


Figure 2.2 Map of western Uganda and surrounding regions to illustrate sites (marked in red), modern towns (in black), kingdoms (capitalised in green), important regions (in green), and rivers and lakes (blue) mentioned in the text

---

Part Two: Political and Social Organisation

As has been explained, the resources available to someone attempting to reconstruct the past few thousand years of history in western Uganda are somewhat limited, and as such much of what follows is tentative rather than definitive. However, in very brief summary, Peter Robertshaw (who has written extensively on the archaeology of western Uganda) sees the development of political complexity in the region as comprising two distinct stages. A sparsely populated frontier region prior to the second millennium AD, diverse mixed-farming communities gradually settled in the lush lands to the north of the Katonga River between the eleventh century and the end of the fifteenth, culminating in the growth of several competing small polities and the construction of earthworks sites. At the beginning of the sixteenth century, a shift to a drier climate coincided with the appearance of a more dispersed settlement pattern, a greater emphasis on pastoralism, and, eventually, the emergence of the Bunyoro kingdom (Robertshaw and Taylor 2000; Taylor *et al.* 2000; Robertshaw *et al.* 2004).

Drought and migration appear to be two of the key themes that repeatedly reoccur in constructions of western Ugandan history, linking interpretations of the environmental, archaeological, linguistic and oral historical datasets. The Great Lakes region was subject to periodic, severe droughts in the second millennium AD. Tantala argues that in western Uganda these contributed not only to major, periodic social and cultural reorganisation, but also a gradual shift towards pastoralism, as those families that emphasised cattle keeping recovered more quickly from these periods of stress than those who depended more on agricultural activity (1989: 498; also Steinhart 1981; Schoenbrun 1998; Robertshaw 1999: 129). Droughts disrupted old power structures, allowing ambitious new leaders opportunities to seize power during the recovery phases that followed (Tantala 1989: 478-504, see especially the example of Kitara kya Nyamenge). Migrations that accompanied droughts meant that "most groups experienced a new ethnic mix, a new location and new leadership" (Webster *et al.* 1992: 782), providing new opportunities for social change and innovation. These themes will be frequently addressed in the narrative that follows as the above summary is expanded upon, explained and justified.

TRADITIONAL HISTORIES

This region is home to traditions and foundation myths too many and too complex to summarise in any justifiable depth in the short space available here, not least the detailed discussions regarding the possible historical basis of these stories and the conflicting nature of many of the accounts. Accordingly, instead of attempting to reproduce even the most significant stories here, I will present only an essence of the major figures and themes that have at various points been attributed with historical connections. This will provide a foundation for understanding the development of later archaeological research in the region (*cf.* Schmidt 1990), as well as introducing and contextualising important terminology that is relevant to upcoming parts of this and future chapters.

In summary, Nyoro court histories generally focus on three consecutive dynasties. The earliest is the Batembuzi – portrayed as an invading, pastoral dynasty in existence from "time immemorial" (Uzoigwe 1979: 28), who are said to have imposed monarchical rule over an existing agricultural population and who originally founded the Kitara 'empire' (*cf.* Chapter 1). They are considered by most scholars to be fictional figures of myth (Robertshaw and Taylor 2000), yet it is sometimes supposed that traditions surrounding this dynasty refer to events from around the eleventh century AD (Buchanan 1974b; Tantala 1989).

The successive, but apparently short-lived Bacwezi dynasty – not to be confused with the Bacwezi spirit mediums of the nineteenth and twentieth centuries (see Berger 1980) – appear in foundation stories of the traditional histories of many Great Lakes kingdoms, including Buganda, Bunyoro, Buhaya, Nkore, Karagwe, Rwanda, Buha, Burundi and Bushi (Chrétien 2003: 95-103). A 'Great Drought' is often said to mark the end of the Batembuzi period, and the start of the following Bacwezi period (Tantala 1989: 477), though it is possible that this is more a literary device than a discernable event. The Bacwezi, like the Batembuzi, are considered by some (e.g. Wrigley 1958) as mythological beings or gods, but are seen by others (especially historians of the 1950s and 1960s) to represent the leaders of an early fourteenth to fifteenth century empire centred on Kitara (Oliver 1953; Ogot 1984) that extended the dominance of Bunyoro to as far south as Rwanda, west over the Rwenzori Mountains, and north and east past Lakes Kyoga and Albert (Kiwanuka 1968a). The notion of an extended Cwezi 'empire', with the Bacwezi described as pale skinned foreigners ruling from capital sites that have remained in the archaeological record (*cf.* Cole 1954; Posnansky 1966), held ideological appeal within a colonial setting, and continues to infiltrate popular belief today (Robertshaw and Taylor 2000; e.g. Kihumuro-Apuuli 1994; Kikonyogo 2010). However, more recently, the suggestion that the Bacwezi were in fact rulers of contemporary and competing small-scale localised polities has been strongly made: "religious and cult leaders that may have had local political authority" (Uzoigwe 1979; Robertshaw and Taylor 2000; Schmidt 2006: 256; though see Buchanan 1974b, who conceptualises the Cwezi instead as a historical dynasty). It is during this period that the development of ironworking knowledge and intensification of agriculture is often credited (Uzoigwe 1979: 28; Schmidt 2006).

The final dynasty was the Babito, who comprised the ruling dynasty at the time of European contact, and who ruled (according to several proposed kinglists) from approximately the late fifteenth or early sixteenth century (Robertshaw 1994: 106; Chrétien 2003: 475). This dynasty is described as having originated out of the southwards raids of a northern 'Rivers and Lakes' Nilotic group, the Lwo (Beattie 1960; Nyakatura 1973 [1947]). This conjecture seems, at least in part, to be historically accurate, with traditional narrative accounts strengthened with linguistic evidence. Several Lwo words remain as part of the Lunyoro language (Crazzolara 1937; Chrétien 2003: 101-102), including the royal greeting '*okali*', a word of Nilotic origin (Ingham 1975: 25). Several names of Banyoro clans are also very similar to Acholi *paks*, such as PaUma/Bahuma, PaLema/Bahema, and official 'drum names' of Bito kings seem to be "Bantuized" versions of Acholi words (Oliver 1955: 115). Once the Babito were established, Nyoro traditions say that the first Babito princes divided this part of Uganda into two kingdoms: Kitara and Buganda (Babiiha 1958). Although there is no further evidence to suggest this was in fact the case, and it is at odds with Ganda tradition that sees the Buganda polity as an independent development, it once again links the early traditional histories of these two polities, ideologically if not in historical reality[2].

From these mythologies a popular chronicle of the origin of Kitara and Bunyoro emerges. Much is highly debatable, and much has been written of the circumstances that surrounded this history's construction at various times. However, an overriding

[2] That is to say, these traditions, recorded within the last century, may well be a nineteenth or twentieth century construct, inventing and rationalising a past in order to help negotiate contemporary political positions.

theme of the complete collected histories is the wide-ranging, inclusive, multi-ethnic nature of the wider 'Kitara', past and present (*cf.* Buchanan 1974a; Tantala 1989): populations are frequently said to arrive in the region to be encompassed into the social landscape. Doyle (2006b) highlights this as an unusually positive feature. Stories regarding the convergence of many different peoples over many different time periods have stressed the value of inclusion and cooperation, culminating in what Kopytoff (1987: 51) describes as "anomalous communities". As Buchanan (1979: 91, referencing Beidelman 1970) also states, "Kitara traditions make no claim to clans having 'all dwelt together in one land or origin,' or 'arriving *en masse* in a great trek, thus providing a rationale for unity'." Doyle (2006b: 468) recognises that such accepted pasts, whether "invented or manipulated … can be a force for social inclusion and stability" – a valuable feature in a wider region often characterised by social disharmony (e.g. Chrétien 2006).

EARLY SETTLEMENT AND ENVIRONMENT (PRIOR TO 1000 AD)

Within the Great Lakes region as a whole, the period between 10,000 and 5000 years ago was considerably wetter than now, getting increasingly drier through the second and first millennia BC. This drying phase corresponds with receding forests and swamps, due to a combination of climatic change as well as gradually increasing land clearance. This "biogeographic" change accelerated from about 1500 to 2000 years ago until, at approximately 1000 AD, the landscape became similar to what is seen now (Taylor *et al.* 2000; Chrétien 2003: 44). However, this generalised overview is only partly applicable to western Uganda.

Since little archaeological data exists for western Uganda before the second millennium AD, many of the reconstructions of past activity in this region are based on proxy environmental evidence. Palaeoenvironmental reconstructions from lake sediments have been able to provide a rough indication of vegetation from which climate changes and anthropogenic events can be inferred. Data derived from sediment cores from Kabata Swamp (near Fort Portal, located just to the west of Mwenge, *cf.* Figure 2.2) suggest that medium altitude moist forest replaced grass and scrubland over large parts of western Uganda between 12,200 and 10,000 BP, during a period of increasing rainfall (Taylor *et al.* 1999). This forest is disturbed and begins to recede in the late second millennium BC. Two possible (and very different) scenarios are suggested to explain this change in vegetation, either an increase in human population in the immediate area (Schoenbrun 1993b) or heavy rainfall causing erosion (Taylor *et al.* 2000). If this change was due to people moving into western Uganda, these early communities left little other trace of themselves in the landscape. To date, the only evidence that is available as to the presence of Stone Age populations are occasional, undated surface scatters of quartz flakes and artefacts, including microliths (Robertshaw 1994; Connah 1996; MacLean 1996), often on high ground (MacLean 1994/1995), and often in association with (although not necessarily co-terminus with) Late Iron Age (LIA) sites (Robertshaw 1991a, 1994).

The region is also apparently lacking in 'Neolithic' sites, or sites showing evidence of a transition between stone using and iron producing communities (*cf.* de Maret 1994/1995), although such sites are widespread in the Gregory Rift and in the savannah environments to the east of Lake Victoria. Similar sites are yet to be discovered to the west of the lake, although there is linguistic evidence for these communities here (Taylor *et al.* 2000). To the south of this research area, on an island in the Kagera River, Late Stone Age (LSA) Kansyore pottery (associated broadly in the region with dates of between 8000 and 3000 BP, Dale *et al.* 2004) was found associated with communities that fished and hunted wild game (*cf.* Dale and Ashley 2010). Kansyore pottery was also found around the northeast shore of Lake Victoria (Lane *et al.* 2006). No such pottery was discovered during Connah's survey on the shores of Lake Albert and the more northerly rivers (Taylor *et al.* 2000), during Robertshaw's survey of more inland areas (Robertshaw 1994), or during MacLean's survey in Rakai district (MacLean 1996).

At about 500 BC, at the onset of what is generally termed the Early Iron Age (EIA), the lake cores from Kabata Swamp show a much stronger indication of forest clearance accompanied by degraded soils, which Taylor *et al.* (2000) suggest indicates the establishment of relatively permanent farming producing a tangible effect on soil quality. Across the wider region, this EIA period tends to be associated with archaeological evidence including charred crop remains, finely produced Urewe pottery (Hiernaux and Maquet 1960; Posnansky 1961b; Ashley 2005; Lane *et al.* 2006) and early iron working remains; this proxy evidence from Kabata Swamp for a surge in agriculture suggests that western Uganda is broadly conforming to this pattern.

The linguistic evidence also appears to corroborate this. It indicates that several central and eastern Sudanic-speaking societies colonised the area between Lake Victoria and the Western Rift Lakes before 500 BC, building an economy based on mixed farming, herding cattle and growing sorghum, as well as forging iron (Schoenbrun 1993a, 1998): "mostly they [Central Sudanic] were known by later migrants as expert iron-miners, smelters and blacksmiths" (Webster *et al.* 1992: 777). Schoenbrun suggests that these communities restricted themselves to land of low altitude, especially to the east and northeast of the Rwenzori Mountains (where Kabata Swamp is located). However, these sites have also so far proved to be close to invisible in the archaeological landscape of western Uganda: "a rather surprising phenomenon that is becoming increasingly difficult to explain away as stemming from a paucity of research" (Robertshaw and Taylor 2000: 13).

Episodes of intensive archaeological survey in western Uganda and north-west Tanzania have often failed to locate any Urewe ceramics at all, including the survey that was carried out around Mawogola (Reid 1991), Karagwe (Reid and Njau 1994), Akagera (Lugan 1983), Bunyoro (Robertshaw 1994) and along the shores of Lake Albert (Connah 1990), although occasional fragments have been recorded upon excavation. This contrasts strongly with the frequency of Urewe finds in Buhaya, Burundi and Rwanda, and more recently in Buganda. When present, the sporadic examples of Urewe ceramics in western Uganda have tended to be found in association with LIA ceramics, although "only a few sherds at four or five sites" (Robertshaw 1994: 115). This has led Robertshaw (1994: 115) to infer "that there was very little agricultural settlement of the Bunyoro-Kitara region during the EIA". Once again, this is a trend that was also noted during the survey for this research (*cf.* Chapter 4).

It is perhaps important to note that the regions listed above that are seemingly devoid of EIA settlement are all comparatively dry areas during this period (Reid 1994/1995). Urewe in general is almost exclusively found around the shores of Lake Victoria and in 'riverine' environments, or, in the case of Burundi and Rwanda, in well-watered forests and hill-and-valley ranges (Reid 1994/1995; Schoenbrun 1994/1995; MacLean 1996; Giblin 2010). As such, it has been suggested that at least up until the tenth century AD, people preferred to locate agricultural settlements in wetter environments, close to lake and river shores as well as the western rift highlands, especially Burundi and Rwanda. Grassy areas with lower rainfall were seemingly mostly neglected (Sutton 1998: 69). Indeed, Urewe sites *were* found during MacLean's survey in Rakai, in what is a wetter and lusher environment than much of the rest of western Uganda. These sites were situated "invariably on prime agricultural land" (MacLean 1996: 299).

The archaeology of the EIA further to the south (in the area encompassing Rwanda, Burundi, northwest Tanzania and eastern DRC, as well as the areas just mentioned in Uganda around the shores of Lake Victoria) provides a different picture of EIA activity. In addition to a larger body of Urewe ceramic material, EIA burials with grave goods including Urewe ceramics, cowrie shells and iron jewellery (Misago and Shumbusho 1992; Giblin 2008, 2010; Giblin *et al.* forthcoming) and a significant number of iron smelting furnaces (van Noten 1979, 1983; van Grunderbeek *et al.* 1983, 2001; van Grunderbeek 1988, 1992; Schmidt and Childs 1985, 1996; Schmidt 1996, 1997; Humphris 2010) have added to the dataset of this period. Many of these furnaces were unusual in that they comprised conical or cylindrical shafts constructed from decorated bricks (van Grunderbeek *et al.* 1983; Schmidt and Childs 1985; Raymaekers and van Noten 1986; Vignati-Pagis 1995; Humphris 2010); some contained evidence for ritual depositions beneath the furnace bases (Schmidt 1978, 1996; van Grunderbeek *et al.* 1983; van Noten 1983; Schmidt and Childs 1985, 1996).

The volume of EIA material in this more southerly region, and the greater extent of archaeologically definable relationships between features and accompanying material culture have enabled a more extensive (if still limited) interpretation of the early social and economic landscapes there. Themes surrounding the stratification of society and technological organisation have begun to be explored using this data (e.g. Schmidt and Childs 1985, 1996; Stewart 1993; Childs 1996; Schmidt 1997; Ashley 2010; Giblin 2010). Even in the most detailed surveys in Buhaya and Rwanda, the predominant finds on Urewe sites are of iron smelting waste. Non-smelting Urewe sites are rare, which might in itself be suggestive of relatively short-term, dispersed settlement patterns that otherwise leave little accumulated trace (van Grunderbeek *et al.* 1983; Reid 1994/1995). Furthermore, as Urewe is not often found in "typical domestic contexts", this might reflect the non-utilitarian value of these ceramics, a question explored in depth by Ashley (Ashley 2010: 145). Most recently, Humphris has proposed a correspondence between the artistic investment put into the decorated EIA furnaces and the finely crafted and decorated Urewe wares, which she contrasts with an increasing simplicity of technological approach through later periods (Humphris 2010).

Nevertheless, in the data-poor regions to the north, discussions of this nature must remain mostly unexplored, at least for the meantime. However, although it seems probable that western Uganda *was* very sparsely populated in the EIA, especially considering the increasing volume of archaeological work, it should be noted that it is an assumption to suppose that such communities in western Uganda would be associated, as in other areas of the Great Lakes, with Urewe ceramics, and as such that EIA sites would be able to be identified by the presence of this pottery type (Connah 1995, in MacLean 1996; Robertshaw and Taylor 2000). Alternatively, this seeming disparity may be due to a scarcity of ceramics rather than a scarcity of sites (Stewart 1993), although it is more likely, considering the density of Urewe ceramics in other Great Lakes regions, that the relative dearth of Urewe sites does mean that the initial populations in this region were comparatively small (MacLean 1996). The lack of early smelting evidence is also notable, one possibility being that EIA communities in the more northerly Great Lakes were iron *users* rather than iron *producers* – an interesting possibility and one that is worth considering (MacLean 1996: 126). Conversely, the retreating forest evidenced in the Kabata lake core may be a reflection of the growth of fuel-hungry iron production at this time (Taylor and Robertshaw 2001), from sites as yet undiscovered.

In summary, across the wider region, the increasing aridity of the first millennium BC seems to have driven the uptake of new technologies as well as encouraging a strategic expansion of cultivation. However, based on the archaeological evidence so far (or rather, the lack of it) it appears that western Uganda, unlike several other regions of the Great Lakes at this time, was a "sparsely populated agricultural frontier at the beginning of the second millennium AD", and when viewed on a macro-regional level, was a largely 'peripheral' area (Robertshaw 1999: 131; 2003).

EMERGING POWER STRUCTURES (C. 1000 TO 1600 AD)

The close of the first millennium saw the onset of a period of major change, with transformations in environmental conditions, cultural relationships, settlement patterns and political centralisation across western Uganda: complex, interdependent factors (Taylor *et al.* 2000). The beginning of the second millennium AD saw a return to a wetter and more humid climate (Robertshaw *et al.* 2004). Pollen cores from a swamp near Munsa indicate that this area was wet and forested before 1000 AD, with a decline in forest vegetation during the period 1000-1200 AD coinciding (counter intuitively) with this time of high rainfall, a strong suggestion of human-induced forest clearance (Lejju 2009). These changes are replicated throughout the Great Lakes: this period sees the transformation of society and environment as populations grow, technology and food production intensify, and power becomes more centralised.

Yet despite these parallels, this region was not a homogeneous entity following a single political trajectory. Robertshaw envisages the limited agricultural settlement in western Uganda prior to the second millennium as an 'internal African frontier' (Robertshaw 1994, 1999; Schoenbrun 1999: 137; *cf.* Kopytoff 1987), a theoretical framework which he uses to explain subsequent developments in the region's history. By 1000 AD, Rutaran-speakers had developed a pastoral-economy between the savannah to the south of the Kafu River and the thick forests north of Lake Albert;

other Rutaran-speakers stayed near the lakes and developed a focus upon banana gardens (Schoenbrun 1993a: 158). At around this same time, farmers – at least some of whom kept cattle as well as those who cultivated grain crops – began to inhabit western Uganda (Robertshaw 1994).

Clan histories (Buchanan 1974a) suggest that immigrations into the area were multifarious and complex, involving people coming from many different directions – this was not "a simple expanding farming frontier" (Robertshaw 1994: 126). Economic change occurred concomitantly with this increase in population. Wet and abundant conditions in this relatively under-populated region meant that there was little or no competition for land (*cf.* Goody 1971). This allowed for the development of a highly diverse subsistence base that exploited a wide range of microenvironments, which in turn ensured that there was adequate 'insurance' against unexpected local catastrophes such as droughts (Robertshaw *et al.* 2004).

Terminology to describe cattle colours and horn shapes increases dramatically in the grassland to the south of the Katonga River at this time, suggesting that cattle herding was thriving; pastoral people were moving into the region with a vocabulary likely developed among Bantu speakers in the preceding centuries (Schoenbrun 1993a). Furthermore, people were beginning to move from more densely populated regions on the shores of Lake Victoria and from the Western Rift (Schoenbrun 1993a, 1998):

> "Some herders possibly sought to escape the social tensions created by narrowing opportunities for gaining access to land suitable for perennial cropping … the shift to cattle was a ready option and afforded rather rapidly expending wealth. To these Rutaran peoples, the open grasslands south of the Katonga must have beckoned. Pastoralism afforded, literally, a way out of problems in the wetter Nyanza littoral and into land that was probably largely if not entirely devoid of human settlement."
>
> (Schoenbrun 1993a: 59)

Somewhat later, between the twelfth and the fifteenth centuries, Schoenbrun also identifies what he describes as a "banana revolution" around the shores of Lake Victoria (Schoenbrun 1998: 167), with banana cultivation increasing in scale and importance, although the earliest presence of bananas in the region is likely to have occurred earlier. Stephens (2007: 139-140) has suggested that the linguistic evidence for banana terminology dates as far back as the late first millennium AD, and recent (although perhaps somewhat anomalous and contentious) environmental evidence may push back the date for the presence of bananas in western Uganda even further, to the fourth millennium BC, with banana phytoliths found at the bottom of sediment cores taken from swamp deposits close to Munsa (Lejju *et al.* 2006).

These varied groups had to establish themselves in a region that was more challenging to agriculture than the shore of Lake Victoria or the Western Rift. Most early settlements remained small (with the exception of the site of Ntusi, to be discussed forthwith) and with little evidence for political stratification before the thirteenth century (Robertshaw 1994). Once the initial difficulties of settling in such a new landscape had been overcome, these various groups, perhaps organised by kin networks, sought power through a variety of means (*cf.* Kopytoff 1987). Such strategies included controlling access to important resources (land, cattle, salt and iron) and controlling religious authority, which in turn attracted followers (especially important in an area of low population), provided labour and enabled the production of surplus – activities which would help people to withstand the periodic droughts that became common across the region (Goody 1971; Robertshaw 1994, 2003).

Several significant sites associated with the early to mid second millennium have been excavated, and these will be briefly described and discussed below. In the early part of this time period, Bwera – a region of grassland immediately to the south of the Katonga River (see Figure 2.2) – was prominent in the region. Cattle-herding was integrated with communities of settled cultivators, seen first at the site of Ntusi (Sutton 1998), a site which heralds the beginning of what Sutton terms the “mid-Iron Age revolution” (Sutton 1993: 69; Ashley 2010; see also Humphris 2010 for a discussion of ironworking in this ‘Middle Iron Age’ in a different area of the Great Lakes). Bwera commanded a central position in the region, instrumental in the development of an economy that combined cereal cultivation and herding (Sutton 1998).

These revolutions occur concurrently with the regional appearance of rouletted pottery, decorated using both carved wood and fibre roulettes (*cf.* Soper 1985): the ceramic marker of what is commonly (and broadly) termed the LIA. An intermediary ceramic style has also been identified – 'Transitional Urewe' – currently primarily recognised around the northerly shores of Lake Victoria, and dated to between the ninth and thirteenth centuries (Ashley 2010), with potential parallels in ceramics found in Rwanda, Burundi and the DRC (Hiernaux and Maquet 1960; Giblin 2010), and Nyanza (Ashley 2005; Lane *et al.* 2007). Similar ceramics have also been found at Munsa (Robertshaw and Taylor 2000). However, although "we know very little about ceramic variation within the Bunyoro-Kitara region in the present day and we certainly do not understand the role, if any, played by pottery in defining or reinforcing political, social or ethnic boundaries in this region" (Robertshaw 1994: 125), this eventual shift to roulette decoration signals a change in craft organisation, which occurs in accompaniment with substantial social and economic change, and alongside increased diversity in settlement and economy (Sutton 1998: 69). In contrast to the EIA, sites associated with LIA ceramics are ubiquitous across western Uganda (Robertshaw and Taylor 2000).

In the wider Great Lakes, terminologies for power and authority also began to develop from around the thirteenth century, with new and meaningful vocabulary for chiefs that indicate a shift of power from hereditary to appointed structures (Schoenbrun 1998: 184-189): "this semantic shift thus clearly demonstrates the increasing importance of economic assets as a socio-political tool at this time, as individual wealth forged a new path to authority, regardless of clan or lineage" (Ashley 2010: 143; *cf.* also Robertshaw 2010). The Entebbe and Luzira figurines suggest that around Lake Victoria a similar shift had occurred, with power beginning to focus on important individuals (Ashley and Reid 2008); parallels can be posited for the emergence of the 'Big Men' that Vansina recognises in regions further to the west (Vansina 1990).

Within this time frame, Ntusi is currently the earliest major site that has been examined so far in western Uganda, appearing to have been first occupied from the tenth or eleventh century AD. Officially recorded for the first time in the early twentieth century, it was subject to a series of excavations, first by Wayland and Combe in the 1920s (Wayland 1934), then by Lanning and Mathew in the 1950s (Lanning 1953, 1970; Mathew 1953), and finally by a team comprised of Sutton, Reid, Kamuhangire and Meredith in the late 1980s and early 1990s (Sutton 1985, 1993, 1998; Reid 1991, 1996; Reid and Meredith 1993).

This expansive site comprises a system of mounds and earthworks, including two mounds known locally as 'male' and 'female', as well as a large earthwork of unknown function consisting of large banks and basins at the centre of the site: the *bwogero*. These earthworks are arranged around the small hills and valleys on which the modern village of Ntusi in Sembabule district is located. The *bwogero* has attracted much discussion as to its function, with no conclusive outcome. Speculations have included reservoirs for water, the protection of crops from elephants, and – like other earthworks in the region – the protection of cattle from raids (Posnansky 1969; Chrétien 1985; Sutton 1985; Robertshaw 2004).

House foundations and postholes are present at Ntusi, as well as evidence both for cereal cultivation (including grinding stones) and herding (Sutton 1993; Reid 1994/1995). Ceramics are in abundance, and there is a small amount of iron-smelting debris towards the centre of the site, which along with the production of ivory items demonstrates some level of craft activity (Reid 1991; Robertshaw 2003). Large refuse mounds "attest a sizeable and concentrated population inhabiting this place over a long period" (Sutton 1998: 49), or as Taylor *et al.* (2000) suggest, regular feasting events. The presence of glass and cowrie shell beads dated to around the thirteenth century indicate that Ntusi enjoyed contact with coastal trading networks by this point (Sutton 1987; Reid 1990).

Ntusi gradually increased in size through the thirteenth and fourteenth centuries, by which time it had expanded to over 100 hectares in area and controlled a number of smaller satellite sites (Reid 1994/1995). The initial construction of this site and its continuing maintenance must have required a large body of organised labour, probably indicative of "a transition from a system of governance based on the family unit to a chiefdom with a much broader power base, involving social relationships outside of kinship and marriage" (Taylor *et al.* 2000: 532). This new form of centralised authority (and the production of agricultural surplus that is likely to have accompanied it) would have provided a considerable buffer against potentially damaging environmental or social events (or worse, the occurrence of the two together), especially if the construction of the earthworks expedited an increase in population and the development of new technologies (Taylor *et al.* 2000). Indeed, "no later settlement in western Uganda is comparable with Ntusi in terms of both overall quantity and density of artefacts and refuse" (Taylor *et al.* 2000: 531), leading Sutton to refer to it as a town (Sutton 1993): this was a particularly large and important site.

Towards the end of the twelfth century, increasing aridity (which was to continue until the beginning of the fifteenth century) is accompanied by gradual changes in settlement and subsistence patterns, with survey data suggesting a rise in the number and size of agricultural settlements in the more humid areas to the north of the Katonga River (Robertshaw 1994; Taylor *et al.* 2000). It has been proposed that reduced agricultural productivity in the drier areas around Ntusi (in light of the increasing aridity) prompted some families more dependent on agriculture than livestock to move north in search of more productive land (Robertshaw *et al.* 2004), although both Ntusi and the surrounding area remained occupied to some degree by agro-pastoralists until at least the seventeenth century.

Still in Bwera, but several kilometres to the north of Ntusi, and much closer to the Katonga River, is the site of Bigo. It was mapped by Combe in the 1920s (Wayland 1934), and later excavated by Shinnie in 1957 (Shinnie 1960) and Posnansky in 1960 (Posnansky 1969). Again, this is a site that stands testament to a large volume of labour and planning. Over ten kilometres of earthworks create "a complicated configuration of embanked and ditched enclosures" (Sutton 1998: 57). There is evidence of occupation in the form of postholes, cattle kraals and refuse disposal, as well as grinding stones, iron reaping knives and cattle bones. The main occupation dates to the fourteenth and fifteenth centuries (Robertshaw 1994: 109), which would make it contemporary with the later stages of the Ntusi occupation, although the earthworks were dug later, towards the end of the fifteenth century (Posnansky 1969). There appears to have been a reduced emphasis on agriculture at this site, and a much less dense population.

Similarities with Nkore capital sites to the south prompted early speculation that this was part of an expansive 'Bigo culture' (Posnansky 1966, 1969), with the suggestion that these large thirteenth to sixteenth century sites were "the material remains of a pastoral people (i.e. the Bacwezi) who had held sway over a wide area of western Uganda" (Robertshaw 1994: 107). Was this a place of particular importance or ritual activity, or a royal capital? Unlike Ntusi, no exotic, traded items were excavated from Bigo (Posnansky 1969), though this may have been due to the excavation strategies implemented at the site (A. Reid pers. comm. 2010). Even so, the possibility of this being a place of royal significance diminishes, making it perhaps more appropriate to see this site as part of a political system of another kind (Sutton 1998).

Together, Ntusi and Bigo (and other smaller Bwera sites) seem to form part of a wider 'Bwera' economy, based on a co-dependent system of cultivation and cattle herding. A flexible approach to subsistence seems by this time to have transformed this part of peripheral western Uganda into "a core area, in which corporate power strategies facilitated the development of larger polities (complex chiefdoms?) than had existed previously" (Robertshaw 2003: 161). Yet, at the beginning of the fifteenth century, Ntusi appears to fall into decline (Taylor *et al*. 2000). Sutton suggests that this is due to over-exploitation of soil and forest resources (Sutton 1993), and Lejju *et al.* (2003) agree that the decline does seem to follow a period of increased burning of forest and a greater prevalence of degraded soils. Palaeoecological records denote that a phase of forest recession began in the early fifteenth century, which carried on until the middle of the seventeenth century (1419-1648 cal. AD). This appears to correlate with the decline of extensive, permanent settlements (especially Ntusi) that were located in the drier, southern parts of the region (Taylor *et al.* 2000). Bigo appears to have been abandoned shortly thereafter. As such, climatic and/or ecological factors may have contributed to this scenario. Sutton (1998) suggests that a number of significant changes in social and economic environments meant that the pastoralist and agriculturalist elements of this larger economy became increasingly polarised. By about the sixteenth century, this 'Bwera system' appears to collapse completely, ending this phase of apparently competing, mixed economy contemporary polities.

A return to more humid conditions from about the fifteenth century coincided with more extensive forest clearance to the north of the Katonga River (Taylor *et al.* 1999). This clearance may have begun in the preceding drier period, and is taken to be indicative of the growing importance of agriculture there (Robertshaw and Taylor 2000), evidenced by the emergence of settlement and earthworks sites at Munsa, Kibengo and Kasunga by the latter half of the fifteenth century, around the time of Ntusi's decline (Robertshaw *et al.* 2004: 541). Various strategies are likely to have been implemented in order to secure power, including raids on neighbours for cattle and women, control of surplus food, and monopolies on ritual and religious authority (Robertshaw 1999). Once again, these sites have been supposed to be the capitals of contemporary polities (Robertshaw *et al.* 1997; Taylor *et al.* 2000). Excavation revealed comparatively little occupation debris except at the very centre of each site, and unlike the earlier sites of Bigo and Ntusi, agriculture now seems to be dominant, although there was still some cattle keeping.

The site of Munsa, described by Lanning in the 1950s (Lanning 1953), was later excavated by Peter Robertshaw (Robertshaw 1997). The earliest settlement there appears to occur at around the thirteenth or fourteenth century, earlier than the construction of the earthworks at the site of between the fourteenth and fifteenth centuries (Robertshaw 1994: 109). The ditch systems at Munsa (and Kibengo) may have been funded by agricultural surplus created by the earlier period of high rainfall. Furthermore, ironworking was undertaken at Munsa, as evidenced by a single furnace, probably fourteenth century, which was located at the centre of the site. Robertshaw (2003, 2010) suggests that this may link the control of iron production (and as such the production of, for example, agricultural tools) to elite sectors of society, although occupation debris was also limited to the centre of the site. Nevertheless, there is little evidence to suggest a strongly elite presence at Munsa. Two early burials, dating to between the ninth and eleventh, and eleventh to thirteenth centuries, contained glass beads that indicate contact with long distance trade networks; later burials did not have recoverable grave goods (Robertshaw 1997). However, at approximately 1520 AD there was another shift to lower rainfall (Robertshaw *et al.* 2004), again heralding change; these drier conditions (and accompanying insecurity) may well have given advantage to those living in or near these earthworks. The large storage facilities in evidence at Munsa hint at a growing need to respond to dwindling food security (Robertshaw 1997), or, feasibly, increasing socio-economic stratification.

Further north, an important industrial site was also growing: Kibiro, one of two major salt production sites in the region (the other being Katwe to the southwest). Following initial work by Hiernaux and Maquet (1968), Connah led extensive excavations and survey around the site in the 1990s (Connah 1996). By the thirteenth century, Kibiro was flourishing as a centre of salt production: a specialised settlement probably dependent on trade with nearby agricultural markets to feed itself (Connah 1991). Glass beads in a thirteenth century burial context indicate that long distance trade and the accumulation of wealth were important aspects of Kibiro's economy and society (Connah 1996). The deeply stratified archaeological deposits there indicate "substantial occupation and large-scale salt-production", which in recent years at least has been an exclusively female occupation (Connah *et al.* 1990: 28, 35). As stated previously, there is no evidence of settlement at Kibiro before the second millennium; people had migrated there from elsewhere, perhaps close by, already using roulette-decorated pottery. The use of carved wooden roulettes suggests links with areas to the north of the Victoria Nile, which is supported by both linguistic and oral traditional evidence (Oliver 1977, 1982). This correlates with suggestions of a "widespread infiltration of what is now north-western Uganda by people from the north" (Connah 1996: 216), which Robertshaw believes may reflect the Nilotic contribution to the subsequent establishment of the Nyoro kingdom (Robertshaw 1994: 111).

Robertshaw's analysis of survey data identifies a generalised trend of shifting settlement patterns during this time, from "large, apparently concentrated villages located on ridge tops and/or close to rock outcrops, to dispersed homesteads situated on the lower slopes of hills, the pattern that is still extant" (Robertshaw 1991a: 44; 1994: 116). Although this is necessarily a simplified view, and there is no means as yet to date this transition, he also suggests (through an examination of site size) that there was increasing social and political stratification across the region. However, more data, better sequencing and improved dating are needed before this can be clarified.

In summary, this innovative period is characterised by "expansion, diversification and specialisation" (Reid 1994/1995: 309), including the exploitation and colonisation of new environments, population increase and the development of new techniques for pottery decoration (Reid 1991). Early major earthworks were possibly the capitals of polities founded on agriculture, though cattle were also kept, perhaps for prestige (Robertshaw and Taylor 2000: 19). A broad subsistence base included both cultivation and pastoralism: livestock was herded alongside the cultivation of cereals, including sorghum and finger millet. In addition to this, two major commodities were produced – iron and salt – which were in great demand across the region and which enabled a further rise in prosperity (Robertshaw and Taylor 2000: 216).

KINGDOMS IN WESTERN UGANDA (C. 1600 TO 1860 AD)

"Between 1600 and 1800, in eastern Africa's Great Lakes region, the states of Bunyoro-Kitara and Buganda formed and began to export their bureaucratic, militaristic, and religious hegemony to neighbouring societies."

(Schoenbrun 1999: 136)

From around the seventeenth century, the kingdoms of the Great Lakes – including the major stratified polities of Bunyoro, Buganda, Buhaya, Nkore and Nyiginya – grew and established themselves as the dominant form of political and social control in the region (Sutton 1993; Chrétien 2003; Robertshaw 2003; Vansina 2004). At the beginning of the sixteenth century, there had been another significant shift in climate in western Uganda, with a return to more arid conditions alongside extensive soil exhaustion (Lejju *et al.* 2003). This change in climatic fortune corresponded with a decline in nucleated settlements and large, sedentary populations from the late seventeenth century and early eighteenth century, and the onset of the next chapter in the history of this part of western Uganda (Taylor *et al.* 2000: 527).

By the eighteenth century, major social, economic and political change saw the earthworks abandoned. Capitals became peripatetic, more transitory and (presumably) more difficult to detect in the archaeological record; rural settlements became more dispersed, and there was a growing emphasis on herding. The mixed economy polities that were described in the previous section were, through means that remain unclear, and in contrast to the neighbouring polities of Buganda and Buhaya, replaced by states where power derived primarily from the control of cattle.

The mechanism for this change is largely unknown, although it is likely to include incursions by Lwo (Eastern Nilotic) and Madi (Central Sudanic) peoples into western Uganda[3]. Historical traditions assert that the Bacwezi dynasty was overpowered by the Babito, who were linked to Lwo pastoralists entering western Uganda from the north with superior military strength (Robertshaw 1999). A tradition recorded by Fisher (1911) told that King Rukidi – the first Babito king, with supposedly northern origins (Chrétien 2003) – arrived in western Uganda flanked by bodyguards bearing barbed arrows typical of the Madi[4] (Posnansky 1969).

However, this was not a warlike invasion (Buchanan 1974a: 209; Oliver 1977). The complexities of the transition were probably more subtle, with suggestions of internal warfare and the collapse of previous competing polities creating a political vacuum, perhaps hastened by drought-induced famine and disease, and a drop in population density (Robertshaw 1994). Repeated, prolonged droughts at the end of the sixteenth century would have put pressure on food supply for the large and sedentary population. There is a long-established relationship between rainfall anomalies and

[3] Steinhart (1984) argues that the Nyoro state only emerged in the eighteenth and nineteenth centuries as a result of competition between agricultural and pastoralist communities for resources that were becoming increasingly scarce in response to periodic drought. However, there is no evidence for the polarised agricultural and pastoralist groups prior to the eighteenth century that this hypothesis requires.

[4] A further indicator of the symbolic and communicative power of iron and iron objects.

food security in this region, though data from the twentieth century reminds us that famine is caused by a combination of human and environmental factors, not just low rainfall (Lejju *et al*. 2003). Traditions from both the north (Pawir) and the south (Haya) pinpoint a drought and famine (allegedly induced by witchcraft) as the factor that allowed the Babito to overcome the Bacwezi (Buchanan 1979: 108). The external origins of the Babito have been suggested as offering a particular advantage, putting them above local "social rivalries" and free from prior ties and dependencies (Chrétien 2003: 148). Furthermore, the Babito appear to have sought legitimisation for their authority by investing themselves with a historical relationship with the Bacwezi (Berger 1980; Steinhart 1984; Tantala 1989; Robertshaw 1999).

Thereby, the Nyoro kingdom, ruled by the Babito through local district chiefs and sub-chiefs, came to unify much of western Uganda into a single state (Robertshaw 1994: 127). Throughout the Great Lakes, systems of governance were emerging whose leaders bore the responsibility and ritual power to "arbitrate and further … the coexistence and blossoming of all" (Chrétien 2003: 144). These kingships were based on 'political aristocracies' that demanded respect, subordination and material acquisitions; they were hierarchical and patriarchal. Unlike other regions of Africa, where slavery became a means to achieve these ends, in the Great Lakes "the establishment of monarchies corresponded to the implementation of tributary regimes" (Chrétien 2003: 144).

Accounts differ as to how the Nyoro state was governed. Some assert that it was founded upon a 'feudal-like' system of land tenure, with surplus appropriated through tribute (Robertshaw 2003: 153), and with the Babito in control of access to Bunyoro's strong economic resources: agricultural land, salt and iron (Beattie 1960). Others suggest that although the land belonged to the king, there were no royal restrictions as to where people could settle – "the clan governed the land while the king governed the people" (Beattie 1960: 167) – in marked contrast to Buganda where land was parcelled up and politically controlled (A. Reid pers. comm. 2010). There were no official taxes imposed upon the subjects of the kingdom, although yearly tribute did appear to be paid as an unspoken rule (Roscoe 1915: 18-19). King Rukidi is traditionally attributed with establishing the salt and iron industries of Kitara (Connah 1996: 4), and Kibiro remained an "extremely important source of salt for the pre-colonial Nyoro kingdom" and their cattle (Robertshaw 1994: 110).

The king's capital housed around 500 residents, much less than in neighbouring kingdoms, where numbers could reach up to two thousand (Bukeye, Burundi or Nyanza, Rwanda) or even twenty thousand in Buganda (Chrétien 2003: 166), and these capitals were itinerant and subject to move. The peripatetic nature of the new royal centres offered several advantages. They could be relocated if necessary for tactical reasons, whether aggressive or defensive; it minimised accumulations of waste; and importantly it facilitated regular access to fresh grazing ground, especially if drought or local grass exhaustion arose (Robertshaw *et al.* 2004). District chiefs were expected to keep permanent representatives at these courts, and to visit regularly, thus allowing the *omukama* (king) a certain degree of control over his kingdom (Chrétien 2003: 177).

Wars of succession commonly occurred and the size of the state and the degree of central control fluctuated over time (Robertshaw 1999: 126). Incursions by Baganda into Nyoro lands were common (Roscoe 1915: 81), and the ensuing wars are a regular theme in the oral traditions of both kingdoms (Oliver 1955). Bunyoro also frequently raided other neighbouring kingdoms, including Nkore and Bakedi, in order to increase stocks of cattle (Roscoe 1915: 81; Webster *et al.* 1992); resistance to Banyoro invasion is an important kingly tradition in, for example, Nkore and Karagwe. Through these raids, Bunyoro remained "the most powerful kingship for many years" (Chrétien 2003: 147).

With the growth of this cattle-based state, sites associated (in clan histories) with the Bacwezi became shrines connected with agriculture, fertility, rainmaking and iron production (e.g. Mubende Hill), focal points of resistance against the power of the pastoral state (Buchanan 1979: 110; Robertshaw 1994: 108). This transition may well have cemented the oft-presumed relationship between the Bacwezi and these economic features (e.g. iron and agriculture), although unlike other kingdoms in the region, a strong social divide between pastoralist and agriculturalist did not emerge in Bunyoro (Willis 1997). Several clans (including the Grasshopper, Buffalo, Crow and Heart clans) are thought to have left Bunyoro for Buganda during this time in order to escape Babito rule (Buchanan 1979: 110).

Nevertheless, Bunyoro lacked powerful management and was only loosely organised. Its administration was decentralised, with "autonomous peripheral principalities" in Bwera, Kooki, Buddu, Kiziba and Busoga: it was an "undoubtedly too-vast cluster" by the eighteenth century (Beattie 1960; Dunbar 1965; Chrétien 2003: 148). The droughts that may have contributed to the development of this Nyoro state also impacted on its later history. Reduced food security, in conjunction with interruptions in trade due to repeated war, probably facilitated the secession of Toro and the land bordering Buganda. Under the rule of the Ganda *kabaka* (king) Katerega, Buganda expanded as far south as the Katonga River. In the mid-eighteenth century, Buddu was taken from Bunyoro. Finally, in the nineteenth century, Buganda took Singo (Oliver 1955; Uzoigwe 1972). Such war, coupled with climatic insecurity, was a major cause of famine for Bunyoro in the late nineteenth century (Doyle 2000; Robertshaw *et al.* 2004: 542). Ultimately, "the kingdom of Bunyoro, once the most powerful state in the region, declined significantly in territory and power" from this period onwards (Robertshaw *et al.* 2004: 542), with Buganda and Rwanda emerging as the new 'super-powers' of the Great Lakes (Webster *et al.* 1992).

EUROPEAN-NYORO RELATIONS, COLONISATION AND INDEPENDENCE (1862 - PRESENT)

It was during this period of decline that a further, new factor entered the arena that was to have serious consequences for the future of the Nyoro kingdom. In 1862, the first Europeans arrived in western Uganda. The explorers Speke and Grant passed through Bunyoro when *omukama* Kamurasi was at the head of a kingdom depopulated by war, famine and disease (Beattie 1960: 17, 22). At this time, the kingdom was no longer a coherent political unit and there were frequent revolts, royal dissent and constant wars with Buganda. As mentioned previously, in the late eighteenth and early nineteenth centuries, several outlying areas of Bunyoro had already fallen to Buganda, some having been conquered, others transferring their allegiance to the newly rising power (Ingham 1957: 133). Kooki, "little Kitara in the southeast" (Ingham 1957: 133), and Buddu defected in the eighteenth century (Kagwa 1918: 160); Nkore expanded northwards into Bunyoro in the nineteenth century; finally Toro seceded from Bunyoro at around 1830 (Uzoigwe 1979: 46). Mwenge became heavily contested land, situated between the Toro and Nyoro kingdoms (*cf.* Ingham 1975).

Speke and Grant's visit, although of only a few months and on the surface reasonably friendly, was marred due to the arrival of the explorers with a Ganda escort: suspicions of the allegiance of the visitors were already raised. The European/Nyoro relationship deteriorated further a year later, with the arrival of Samuel Baker and his wife. His difficult personality pushed the already sensitive relationship, and his subsequent description of Kamurasi comprised accusations of "treachery, cowardice, and greed" (Beattie 1960: 18). Again, the Bakers had arrived in the company of the wrong people – this time Sudanese raiders – once more setting the relationship off on a difficult footing. The Bakers left in 1864 and returned eight years later, two years after *omukama* Kabalega had been appointed to the throne. The Nyoro-European relationship went rapidly downhill, with accusations of poisonings, shootings, and general mistrust on both sides (Beattie 1960: 17-19).

Unfortunately, most future dealings between Bunyoro and European visitors were marred by these early encounters, with Baker's defamatory reports influencing future governors. An exception was Emin Pasha, who succeeded Colonel Gordon as governor of Egyptian Equatoria in 1878, and who got on well with Kabalega (Beattie 1960: 21). But when Emin left in 1889, Kabalega resumed raids on Buganda and Toro, regaining territory, restocking cattle, expanding trade and generating new wealth for a revival of the kingdom (Robertshaw *et al.* 2004). Regaining this strength worried the Europeans and relations turned once again to hostility.

In 1890, Captain Lugard arrived in Uganda with the British East Africa Company, to oversee the lands of Buganda and Bunyoro. Again, the approach to Bunyoro was significant: Lugard entered Bunyoro from Buganda and was highly influenced by Ganda propaganda against the Banyoro. Three years later, a force of over 15,000 soldiers (mostly Baganda) invaded Bunyoro under European leadership. Kabalega fought back against the imposition of colonial rule and managed to defy capture and defeat until 1899, at which point he was exiled to the Seychelles, never to return (Beattie 1960: 22-23). Bunyoro had finally been "smashed by force" (Oliver 1955: 112-113).

The trajectory of these negative relations rested heavily on the longstanding hostility and competition between Bunyoro and Buganda. Unfortunately for Bunyoro, Buganda won the favour of both the British trading companies and the Protectorate Government, and as such Bunyoro automatically found itself "on the wrong side of all of these forces" (Oliver 1955: 112). Not only was the king exiled and much of the Nyoro population controlled by their Baganda enemies as local chiefs, several significant areas of land were given to Buganda in the 1900 Uganda Agreement (Beattie 1960: 22). These were termed the Lost Counties, and they included Buyaga and Bugangaizi – "the historical centre of the country", the "core of the ancient kingdom", where the graves of former kings and significant ritual sites were situated (Ingham 1953; Oliver 1955: 113).

These events coincided with a further period of low rainfall between 1880 and 1900 that culminated in a very severe famine in 1898 to 1900. This, alongside the "destructive war of colonial conquest" (Robertshaw *et al.* 2004: 542) and a rinderpest epidemic, almost completely depopulated the kingdom (Doyle 2000). Epidemic disease spread unusually easily due to conditions forced upon the population because of war: anti-famine measures (grain storage, trade networks) had been broken down, and British forces destroyed crops and livestock to subdue disloyal villages. There was no food, and a complete breakdown of the traditional ruling system resulted (Robertshaw *et al.* 2004). Social instability returned.

However, in 1933 the Bunyoro Agreement was signed with the Protectorate Government, which gave Bunyoro the same political status as Buganda, even if in practice it failed to afford it similar political weight (Beattie 1960: 23). The colonial period, also marred by regular famine and food shortages, came to an end in 1962. Five years after independence, all Uganda's kingdoms were disbanded with the express aim of harnessing a more united approach to a newly independent republic, although a more realistic reasoning may be that it allowed the new President Obote to appropriate their wealth and power. However, they were officially restored in 1993, and Bunyoro is now formally called Bunyoro-Kitara.

PART THREE: IRON WITHIN WESTERN UGANDA

"None of these resources, not clay, kaolin, coffee or barkcloth, rivalled the importance of iron bloom and salt in Lakes homesteads."

(Schoenbrun 1993b: 26)

Early thoughts of the inception of Nyoro smelting were not immune from the widespread colonial presumption that any ironworking knowledge held by Bantu Africans must have been acquired from more civilised outsiders: "the totally savage Negro received his knowledge of smelting and working iron" from the "superior races coming from the more arid countries of Southern Abyssinia and Galaland" (Johnston 1902: 486). Fisher (1911: 3) believed that the most likely source, in the case of Bunyoro, was Egypt. She thought that as the Egyptians travelled along the Nile, "doubtless they instructed the natives in the working of iron which is very plentiful throughout the country". Yet, later, there were more considered insights. Wainwright (1954: 116-7) examined language, trade routes and bellows style. He believed that if the technology had come directly from Egypt (or equally, Indonesia), then there would have been Egyptian-style bellows or Indonesian names for ironworking in Bunyoro. Instead, he postulated a more gradual diffusion of knowledge, although ultimately originating in Meroë, Sudan. Roscoe's thoughts were more cautious:

> "Years ago the native, in some unknown way, became acquainted with the use of metals, and from this land went forth in early ages a knowledge of iron-working and smelting which revolutionised the world's methods of work … When and how the people began to use iron we cannot discover and they themselves can give no satisfactory account of the growth of the industry, but they have gained a knowledge of the value of different ores, the hard and the soft, and they produce from the amalgamation of the two a metal of good quality."
>
> (Roscoe 1923: 5)

Even now, data and dates remain elusive regarding the early uptake of iron production in this part of western Uganda. However, regardless of how and when knowledge of iron production arose, it is reasonable to assert that iron played a major role in the formation of early power structures in the region, as well as in the consolidation of local relationships and in interactions with neighbouring polities. Iron afforded its producers the opportunity to accrue status independently from hierarchies defined by kinship and obligation. The wetter conditions to the north of the Katonga meant that the landscape tended to be more heavily forested, increasing demand for hoes, axes and machetes. This was combined with an emphasis on cultivating finger millet, a comparatively labour-intensive crop, which boosted local need for agricultural tools (Robertshaw and Taylor 2000). Demand for high quality weaponry would also have been considerable, especially in view of the frequent hostilities in the region caused by regular dynastic and territorial disputes (Tosh 1970: 106). Iron production greatly benefited the kingdom in terms of war and agriculture, and as such, ironworkers were well respected (Ingham 1975: 16). This is not to say however, that iron was only a functional material, and ornaments and jewellery were (and are) also fashioned from it.

Several Great Lakes kingdoms reveal substantial political linkage between reproductive (transformative) technologies – for example farming, herding and importantly, iron production – and the sovereign as provider and guardian of the state's fertility and success (de Maret 1985; Chrétien 2003: 144). Some, such as Karagwe (Sassoon 1983; Reid and MacLean 1995), Buhaya (Schmidt 1997), Nkore (Karugire 1971; Sassoon 1983) and Rwanda (Sassoon 1983), as well as another nearby

Bantu polity, the Luba (de Maret 1985, 1999) have rituals, regalia and iconography that link iron, king and sometimes cattle, in the form of, for example, royal hammers and spears that were stylistically imbued with cattle horns. Cyirima Rujugira, an eighteenth century king of the Nyiginya dynasty of Rwanda, was buried with two iron hammers as a headrest, along with iron spears, iron tools and iron jewellery (van Noten 1972; Célis 1987: 19-20). In the case of Bunyoro, the inauguration of a new king included a ritual relating to iron production (Beattie 1971; Nyakatura 1973 [1947]). The new *omukama* was given a smith's hammer and anvil, which he would strike four times as a smith would: at that point "the king was now chief of all the smiths" (Nyakatura 1973 [1947]: 199). This echoes a Luba ceremony, where the knees of the king are struck as if *they* were an anvil (Herbert 1993: 134).

A figurative association of the king with smithing and smelting is common in the region, and an important indicator of the role of the king and the role of iron production. The Nyoro coronation ritual is a sign that the *omukama* also claimed a symbolic power over ironworking, in a similar way to other kingdoms in the region. Through this ritual, and the status that presumably went with it, he controlled his valuable smiths and smelters, and as the 'father' of all smiths, inspired respect from his subjects (de Maret 1985; Herbert 1993).

The value of iron is also demonstrated by references to it in the creation stories of Bunyoro. In the story of Ruhanga ('the creator'), heaven is referred to as being supported over the earth by two trees and a bar of iron (Fisher 1911: 70; Dunbar 1965: 10) – a context that reflects the central position of iron in the order of the later kingdom. On a more local scale, informants of Uzoigwe, during his investigation of Nyoro market systems, "consistently argued that iron-working should rank as their most important occupation" (Uzoigwe 1979: 50). There are also examples of the regional importance of the esteemed Nyoro iron industry. In the late nineteenth century, a prince of Bunyoro promised *kabaka* Mutesa that he would pay a yearly tribute of 80 tusks, 600 hoes and 500 loads of salt in exchange for his help to gain the Nyoro throne (Wainwright 1954). International significance is also demonstrated by the territorial expansion of Buganda into Bunyoro in the early eighteenth century, when it gained the iron-producing districts of Kyagwe and Buddu. A key factor behind Buganda's aggression was the desire to gain access to the prevalent iron resources there, as well as to control the local populations who were known to be skilled ironworkers (Reid 2002: 3, 76; Humphris *et al.* 2009):

> "Until kings Kyabaggu and Junju conquered the ore-rich areas of Buddu and Kyaggwe, Ganda people had to trade for bloom and finished iron goods with Wanga (on the Winam Gulf of Lake Victoria, in western Kenya), Bunyoro, and Bukooki."
>
> (Schoenbrun 1998: 26)

> "For all kinds of metal work the [Baganda] household has always to call in the aid of the smith, who is a specialist. He now used scrap-iron brought from Indians, but in the old days he obtained his iron from neighbouring tribes, notably the Ba-Koki to the south-west; there was no smelting done in Buganda."
>
> (Mair 1934: 129)

Iron made a considerable contribution to the local and long-distance trade networks of the region (Uzoigwe 1976: 34). Katwe, Kasenyi and Kibiro became large commercial centres, exchanging salt cakes, grain, barkcloth, vegetables and iron tools, and were frequented by Banyankole, Banyarwanda, Batoro and Baganda. The Banyoro traded directly to Buganda and to the north of the Nile (Lango, Kumam, Iteso), and this trade became an important supplement to subsistence agriculture for the kingdom (Tosh 1970: 105-106). By the nineteenth century, Bunyoro's trade in these "key commodities was apparently important in the maintenance of centralized authority" within the much-reduced kingdom (Connah 1991: 480). By the early twentieth century, the most important production industries were ironworking and pottery, items that according to Roscoe (1923: 217) were produced to a much higher standard than in surrounding states, and the Banyoro have maintained this historical reputation as skilled manufacturers of iron implements into the twenty-first century.

In other Great Lakes kingdoms, such as Buganda and Rwanda, iron was often acquired by the state in the form of tribute (Humphris 2002; Vansina 2004). In Buganda, royal smiths were located at the king's court on three-month rotations: "they had to produce a certain number of tribute items during their stay, yet could sell any overflow for their own profit. These Ganda ironworkers received certain privileges in exchange for their service, including no taxation, free land [and] no other type of mandatory labour" (Childs 1998b: 117). They were said to carry their smith's hammer as a sign of their status (Trowell 1941), and presumably to prevent them being rounded up for sacrifice by the *kabaka*'s guards (A. Reid pers. comm. 2010).

It is likely, although not explicitly stated, that this applied in Bunyoro as well. Certainly, in nineteenth century Toro (under whose power Mwenge smelters would have operated at this time), the Toro *omukama* and his royal household utilised a large quantity of iron objects (Childs 1998b). To supply the iron needed, several master ironworkers were located close to the capital, although in their own villages, to make objects on demand for the king (Childs 1998b: 116). This system of 'part-time independent specialists' was also seen to be the case at Kinanisi, Buganda (*cf.* Humphris 2002). In Toro, one of these master smiths was formally called '*omuhesi omukama*' (or 'smith of the king'), which was associated with a particular clan (Childs 1998b: 116); over time, more and more *omuhesi omukama* were appointed around the kingdom, who had particular skills to fulfil specific needs of the king (e.g. makers of needles, knives, razors etc[5]). These ironworkers were highly respected. In Mwenge, one of the informants for this research (*cf.* Appendix D) stated that ironworkers in Katooke (to the north of Kyenjojo, Figure 4.2) smelted for the king.

In the 1920s and 1930s, mining for iron ore was outlawed by the colonial government, a legality enforced by the *omukama* (MacLean 1996; Childs 1998b), and iron implements were subsequently provided through colonial trade networks. A number of Robertshaw's local informants concurred (1991b), saying that smelting died out by about 1930, following the enforcement of colonial government rules introduced in 1911 that prohibited the mining of pits deeper than three feet, except for latrines and burials. Missionary attitudes towards smelting tended to be negative, as there were sometimes explicit sexual and spiritual elements that offended their Victorian and religious sensibilities: iron smelting was widely discouraged across the region from around this time (*cf.* Herbert 1993). The increasing availability of

[5] The ironworkers of Kinanisi supplied the Ganda *kabaka* with bracelets (Humphris 2002).

European scrap iron also diminished demand for the costly undertaking of primary smelting. However, local smelting and ironworking for local iron needs did continue in rural areas, at least into the 1950s.

Nevertheless, our appreciation of iron production in precolonial western Uganda remains relatively limited, especially considering the complex web of interactions and knowledge that must have surrounded such a valuable technology. What is currently known is outlined below.

ETHNOARCHAEOLOGICAL ACCOUNTS

The earliest European accounts of the iron industries of western Uganda are by Grant and Pasha, who mention smithing in the descriptions of their travels through the region in the late nineteenth century (Grant 1864; Schweinfurth *et al.* 1888). Both were impressed by the number of smiths in action during their visits to the Nyoro royal capitals of Mruli (Grant) and Mpara (Pasha), but implied through their comments that ironworking was not centralised (Grant 1864: 295-296). Both also remarked on the gossip that could be heard at blacksmith's shops – these were important social hubs. At Mpara, Pasha remarked that there were five or six smithies in operation, each with five or six workmen (Schweinfurth *et al.* 1888: 81). Slightly later in time, Baker recorded the presence of blacksmiths at Atada, near Karuma Falls, as well as along the Kafu River (Baker 1888: 295).

The first detailed accounts made of smelting technologies were recorded by Reverend John Roscoe (1911, 1915, 1923), who travelled to Uganda in the early twentieth century, and who wrote accounts and took photographs of the royal smelters in Hoima, and of the smelting technologies of the Kooki and Buddu areas (by then part of Buganda). An account of mining was also recorded by Lanning (1954), when he encountered an old miner (*abahesi b'amatale*) and his friends near Butiti (Lanning 1954: 188-189). He described the miners' methods for prospecting and mining, who had told Lanning that they were guided to the ore by a reddish dung beetle (*kahinda*) that was also later described by Childs' informant only a few kilometres away in the 1990s, this time close to the village of Kirongo. Roscoe (1915: 75) also stated that smithies were found in all parts of Bunyoro.

A detailed account of a complete iron production process in southwestern Uganda was recorded by MacLean (1996), from an informant in Kamugenyi, Rakai (now in southernmost Masaka district) called Kalilo Lwakulya (a smith and former smelter), who was born in 1910 and who had undertaken a smelting apprenticeship in his youth. Of particular interest is the long distance these smelters travelled to collect iron ore, which was sourced in Lwendaula – over 30km and two days journey to the west of the smelting site at Kamugenyi (MacLean 1996: 29). However, by far the most in-depth accounts available are the reports by S. Terry Childs (1998a, 1998b, 1999, 2000) – an accomplished archaeometallurgist – concerning the mining and smelting technologies of a localised area of Mwenge, as well as the social and economic contexts that shaped them. In 1994 she revisited an elderly smelter named Ndunga, who Childs and Robertshaw had interviewed in 1991 whilst undertaking survey in Mwenge. Her in-depth interviews provide an extensive array of detailed and important insights into the technical and social aspects of smelting, and have proved to be invaluable in my explorations of iron production in Mwenge, as well as to other scholars undertaking ethnoarchaeological fieldwork addressing any form of metal technology worldwide.

Although each account should be considered on its own merits, and is a representation of only one individual's memory of smelting, together they build a quite substantial reconstruction of at least some of the technologies in operation in Mwenge in the more recent past. As tends to be the case with accounts of this kind there is a much heavier focus on mining and smelting than other aspects of these technologies. However, they provide (in varying quantities and detail) information about the seasonality of smelts, the markets they fed, the organisation of the participants, the rituals and requirements that surrounded mining, smelting and smithing, furnace style, technical approach and so on, that can be used as a reference point for archaeological inferences (although see Iles and Childs (forthcoming) and

Chapter 3 for more detailed discussion of the many caveats that surround the application of ethnographic knowledge to archaeological interpretation).

Instead of summarising here the detailed information provided in these sources, relevant information will be introduced when appropriate in the forthcoming chapters.

CLANS, CONNECTIONS AND MIGRATIONS

In the Great Lakes, there are many regionally related clans (or extended kin groups), reaching across the borders of both precolonial kingdoms and postcolonial nation states. For example, the Basita and Basingo clans (and indeed many of the major Nyoro clans) have counterparts in Nkore, Buganda, Kigezi and Bukonjo in Uganda, in Ukerewe and Sukuma in modern Tanzania and in Rwanda (Buchanan 1978, 1979: 102; Chrétien 2003: 89, 90). In the past, these social structures influenced patterns of settlement and occupation and offered security and protection to kin and clansmen. Clans were, and still are, strong units (Uzoigwe 1979: 28-29). They established and maintained networks across distant and geographically unconnected clan lands, and drew together dispersed communities "whose leaders possessed a variety of skills, thus forging a powerful connection between clanship … and the composition of knowledge" (Kodesh 2008: 200). Even though Kodesh is directly referring to public healing, this model is likely to be relevant to other arenas of knowledge, such as ironworking.

Although clan and kin affiliation was determined through patrilineage, a mother's clan affiliation retained certain rights over a child, especially in their early youth: it was a complex system of interrelationships and obligations (Chrétien 2003; Stephens 2009). Clan organisation is thought to have been a vital feature of economic life in western Uganda (Uzoigwe 1979: 30-31), playing "a central role in fundamental social changes" (Willis 1997: 584), with many clans traditionally associated with specific specialisations, including the pervading association of the Basita clan with ironworking throughout the region (Buchanan 1974a: 102-104; Robertshaw 1991b).

The clan structure of the Great Lakes is often seen as a mechanism that was used to organise ironworking networks and to protect valuable technical knowledge (e.g. Haaland 1985; Reid and MacLean 1995). A typical representation of ironworking is of family or clan groups led by a male elder who retained control over the specialised technical and esoteric knowledge by carefully choosing apprentices and by being in charge of taboos and rituals (Childs 1998a: 127), protecting the group's technology with "rituals as exclusive as any medieval guild system" (Ingham 1975: 16). Such an association may well mean that clan affiliation is a pertinent issue to address when considering the archaeology and ethnography of iron production throughout the Great Lakes. Group identity on such a scale is, however, rarely mentioned in archaeometallurgical assessments (although a notable exception includes Robion-Brunner *et al.* (2009), who examine similar themes in the context of Dogon iron production in Mali).

Indeed the clan histories of western Uganda do appear to have information that could be relevant to understanding the dynamics of iron production; furthermore, the movements of such clans as traced through oral histories might shed light on the local transmission of knowledge and the development of iron production styles around the region. These sources also provide clues as to where iron production centres were located and how iron production was carried out and valued in the past. Examining iron production within the framework of clan networks offers an opportunity to explore these technologies from an appropriately socially oriented, vernacular viewpoint.

First it is relevant to examine the historical reputation of Banyoro smelters within the region, and the relationship between Banyoro and Baganda smelters and customers. Bunyoro supplied all the iron to "the countries to the south and the east and for many years the Banyoro smiths were superior to the others" (Roscoe 1922: 141-142); the importance of Bunyoro as a centre of iron producing knowledge was emphasised even among their rivals. Buganda continued to get the bulk of its supply of spear blades from its rival Bunyoro even after the defection of the iron-producing Kooki (Roscoe 1911: 234; Uzoigwe 1972, 1979: 34), and Baganda living on the Bunyoro border used to pay their tribute in the cheap and good-quality Nyoro hoes that they bought from Banyoro smiths (Kagwa 1934: 94).

It is an apparent anomaly that Bunyoro would trade spearheads to its enemy, who was often a serious threat (Ingham 1975: 17), demonstrating perhaps the greater significance of trade rather than warfare to local economies. A Ganda myth relates the story of a battle with Bunyoro where all the Baganda soldiers lost their spears. A female member of the Ganda court instructed the soldiers to sharpen reeds into points to use as replacement spears (Kagwa 1934: 24), which although innovative, perhaps indicates the inability of the Baganda to manufacture their own metal weapons. It is also interesting to note Grant's (1864: 293) observation that the spears the Banyoro used were the worst in the region, as all the high quality spearheads produced in the south were at the time being sold to Buganda.

Yet both court and clan histories suggest that Bunyoro (including Buddu at the time) was traditionally a primary source of iron smelting *knowledge* within Buganda (Kagwa 1918: 160). Walukaga, the head of blacksmiths in Buganda, is said to originally have come from Bunyoro (Roscoe 1911: 163, 171, 295, 387); Kimera, the third king of Buganda, is said to have been born in Bunyoro, from where he sent the first iron hoes and spears into Buganda. In the mid-eighteenth century, a Banyoro smelter called Kongonge came to *kabaka* Mawanda and was given an estate in Kyagwe, where he established mining and smelting. The people living in that region maintained a reputation of being "more like Banyoro than Baganda" (Wainwright 1954: 114). Furthermore, a number of ironworking clans in Buganda claim to have originated in Bunyoro. The Genet clan traces its decent from Luija, who was an ironworker living in Bunyoro; the Bushbuck clan trace their line back to Wanyana, who was the wife of an early king of Bunyoro; the Tailless Cow clan trace their ancestry to Katongole, a man from Bunyoro (Wainwright 1942, 1954: 114). These clans all have parallels in Bunyoro, suggesting that Ganda smelting knowledge is likely to be strongly linked to that of their neighbours.

Buchanan in particular has spent time reconstructing the movements of clans associated with western Uganda, which includes those clans associated with ironworking (Buchanan 1974a, 1979). Although Buchanan takes a very 'literal' approach to these clan histories, the kind of gradual movements of kin groups that she describes is perhaps a pertinent starting point when considering the movement of technological knowledge and style. These clan affiliations and movements will be discussed shortly.

Unlike discussions of large-scale, regional population migrations (e.g. 'the Bantu expansion'), recent dialogue has focused more upon smaller scale movements and the diffusion of ideas and knowledge (*cf.* Lane *et al.* 2007; Mapunda 2010: 206-209). An examination of village composition and local migration undertaken by Charsley in the 1960s in northern Bunyoro provides some insights as to the potential mechanisms of this concept. One of his most immediate observations was: "mobility is high and seems a striking feature of the indigenous population" (Charsley 1970: 17). When questioned as to why people moved, reasons given included taking advantage of amenities and better conditions elsewhere, leaving areas damaged by elephants, or escaping from war, instability or sorcery – factors that are equally applicable in a modern or historical setting.

Charsley's paper contextualises and brings alive Robertshaw's hypothesis of early leaders 'attracting and keeping followers' in the region, expressing these symbiotic relationships in a way that is easier to relate to. In times of difficulty, Charsley saw that people moved to places where they had existing kin, particularly agnates (relatives on the father's side) or affines (relatives by marriage); those men of high status who attracted many other family members to them then gained further prestige (Charsley 1970: 17). It is easy then to see how these movements and relationships might naturally develop into more substantial structures of power and obligation:

> "In practice there are few only who have the capacity to attract and therefore guide movement in this way … It appears that it is essentially their higher than normal social standing, deriving from traditional or modern occupations and from heading a substantial family, that qualifies certain people as 'foci' … no doubt personality differences are both positively and negatively relevant to the

> actual outcome. Finally it seems that 'foci' and certain others around them may be expected to be less mobile than others."
>
> (Charsley 1970: 26)

Robertshaw uses this kind of migration mechanism, alongside notions of an internal frontier following a serious drought to model the emergence of the Kitara kya Nyamenge polity described by Tantala (1989: 479). Tantala retells a story of how a man called Nyamenge, accompanied by his followers, escaped from a forest fire and established a new clan-based (Basita) polity, probably only a cluster of villages, centred around a village called Kitara. Their knowledge of ironworking appears to have been the factor that encouraged others to join them (Tantala 1989: 500-504). This is probably representative of how Robertshaw (1999) envisages the growth of the small competing polities that he describes in the first half of the second millennium AD.

Returning to the links between clans and iron smelting, several seemingly different accounts exist of the relationship between clans and participation in iron smelting. Fisher (1911: 36) reported that in order to be a blacksmith, you had to be born into a certain clan, whereas Childs' (2000: 223) informant notes, "you do not select [by] clan at a smelt. You only choose one who knows how to smelt", although in practice, if knowledge is transferred through clan and family links, this may be one and the same thing. A similar extent of variation was noted during the survey for this research. Almost as many informants (three) believed that clan affiliation was an essential attribute for a smelter as those who believed that all that was necessary was a desire to learn the craft (four, *cf.* Appendix D). It is difficult as an outsider to take apart quite how much these concepts might be linked. Would you be more likely to want to learn how to become a smelter if a close family member is already involved? Would you be more likely to experience iron smelting, even if only as an observer, if you were already a member of an ironworking clan? In other words, how (un)likely would it be for a member of a non-iron-related clan to become interested in, or have access to pathways of learning to smelt, even if in theory there were no restrictions on participation? Unfortunately, these questions are difficult, if not impossible to address through the archaeological record, and with local memories of iron production waning fast, they will be increasingly difficult to explore ethnographically.

Yet the desire to take part in smelting, with the prospects of wealth attached to it must have been strong. Doyle notes that marriage in Bunyoro occurred late (at least in more recent centuries), with women often being eighteen or twenty before they were wed, and men being considerably older, due in the most part to a lack of wealth preventing men from being able to afford a dowry (Doyle 2000a: 455)[6]. This highlights the importance of material wealth to the very structure of society, and suggests that the production of iron was indeed very closely tied to the reproduction of society in Bunyoro, a concept emphasised in Childs' accounts of the social constructs of smelting in Mwenge (Childs 1998a, 1999, 2000). It also brings more significance to the memorable phrase coined by Childs' informant: "after all, a hoe bought a wife" (Childs 1999).

Several clans have maintained a strong association with smelting, and Buchanan (1974a, 1979) has pieced together supposed routes of migration of these groups from collected clan histories. Buchanan (1974a: 95) believes that reconstructing migrations from clan histories offers a good representation of the movements of small groups of people across the landscape, unlike the court histories that tend to emphasise large-scale migrations. Others would disagree. Chrétien (2003: 90) reminds us "no "clan tradition" is so authentic as to escape reconstruction and reinterpretation. At best, each clan's geography, combined with elders' firsthand accounts, gives an idea of the clan's history over a relatively limited area (on the scale of Rwanda, for example) and for a maximum duration of three centuries." It must also be remembered that Buchanan only carried out interviews within western Uganda. Furthermore, of the several areas of western Uganda that are reputed to have been hotbeds for iron technology, Mwenge is the only area where clan histories have been comprehensively collected. Although her reconstructions cover a large region, her informant base did not. Nevertheless, they offer an insight into possible interactions between different groups of ironworkers and of the complexity of movements of small groups around the region, and as such will be presented here.

[6] Doyle (2000a: 455) states that in 1904, brideprice was, on average, the equivalent of quarter of a cow, rising to the value of six cows by 1911. By the 1930s, brideprices were so high that the average worker needed eight years to accumulate that wealth. In contrast, we know from other sources (e.g. Childs 1999, see also Appendix D) that one or two hoes might be sufficient payment for a wife during roughly the same period, a more reasonable outlay for a smelter.

Of the Nyoro clans frequently associated with smelting, the largest, the Basita have already been mentioned. Buchanan posits that they arrived from the east, and that they are strongly associated with the areas of Mwenge, Mbale and Bugungu (Figure 2.3). She recounts that Basita traditions assert that they settled in Mwenge prior to the Bacwezi period, and that they associate their settlement with pastoralism and the development of ironworking. She proposes that a 'tentative' interpretation of Basita influence on the ironworking of western Uganda is that they "refined a skill not unfamiliar to earlier settlers of the Kitara complex. Their impact was to make iron implements a more accessible and relatively more common commodity" (Buchanan 1974a: 101-102). Of interest is the route taken *from* Mwenge to Buddu, an area also noted for ironworking, and, as we have seen in the previous section, an area later seized by Buganda expressly for its ironworking capabilities.

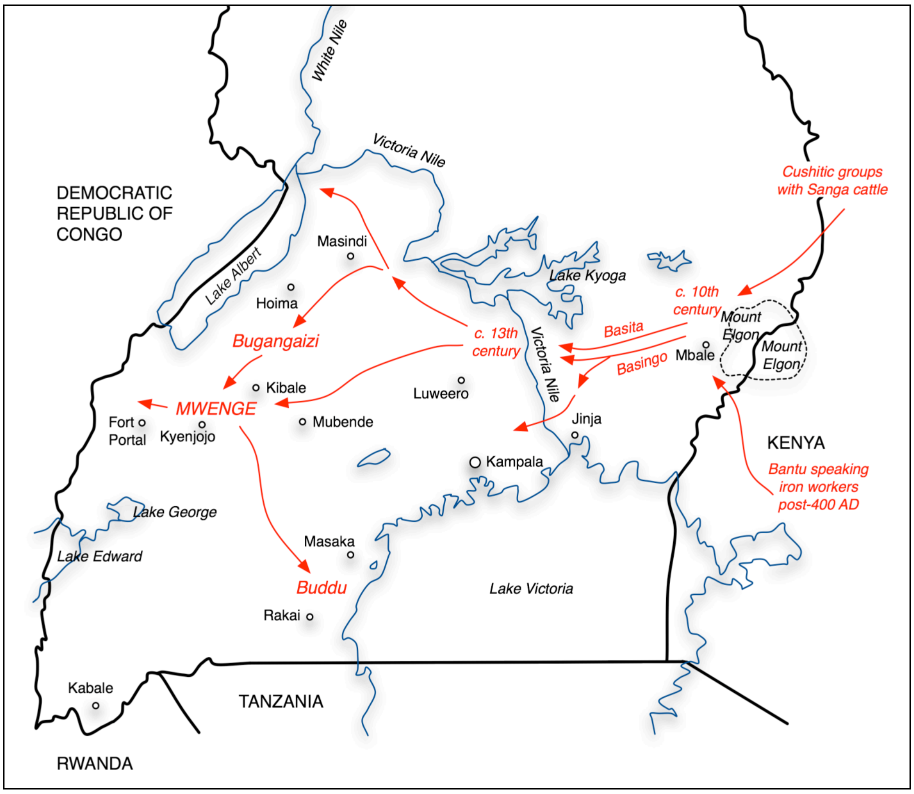


Figure 2.3 Migration routes of the Basita clan as constructed from clan histories (after Buchanan 1974a: 106)

Two further ironworking clans that entered the region during the same time frame (at least according to Buchanan) are the Bagabu and the Babopi (Figure 2.4). Traditions of the Bagabu clan relate their arrival from the north or northwest, crossing the Nile in wooden canoes, and carrying with them knowledge of ironworking (Buchanan 1979: 101)[7]. They assert that their clan *is* the Batembuzi of court traditions. Of note, these clan routes split to the north of Kibale, with one arm going to Mwenge, the other to Buddu.

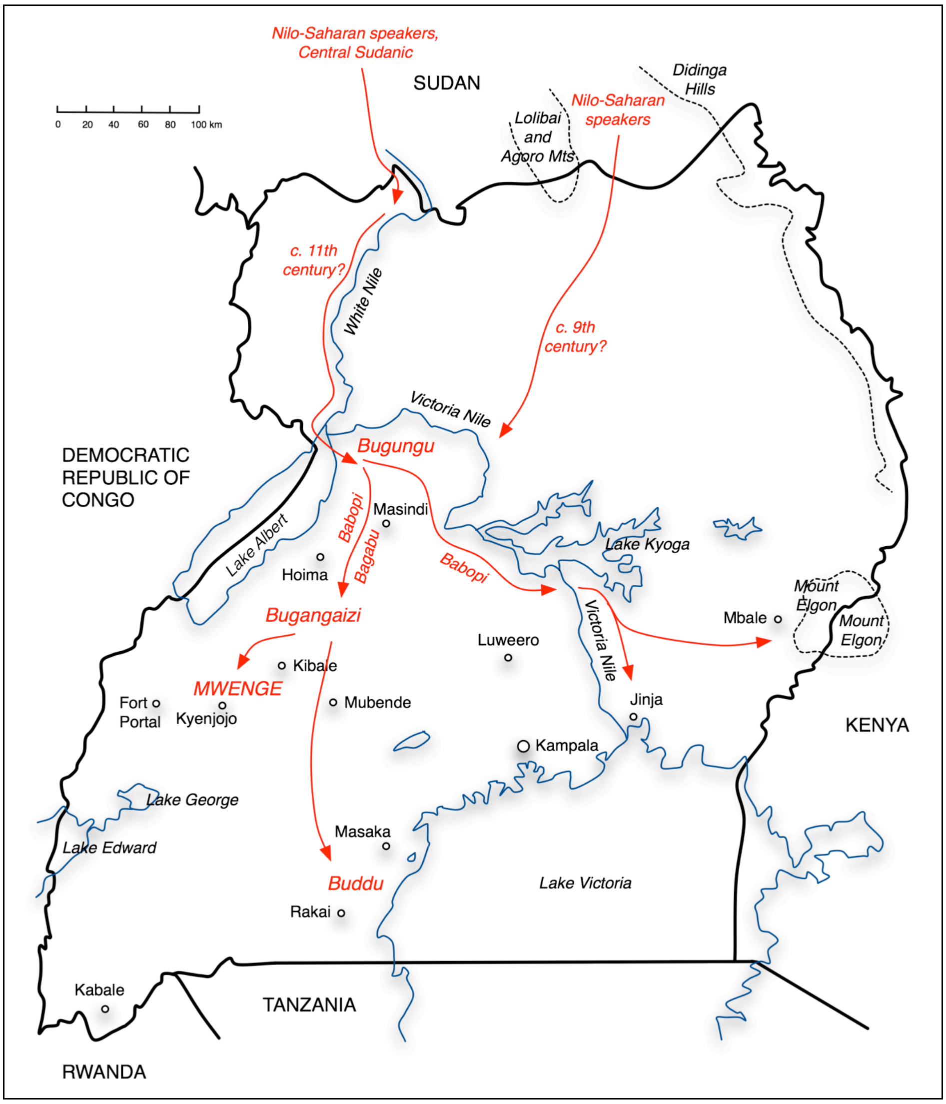


Figure 2.4 Migration routes of the Bagabu and Babopi clans as constructed from clan histories (after Buchanan 1974a: 56)

Buchanan also provides migration routes for the clan that Childs' informant is from. Childs' informant Ndunga, whose account of smelting will be discussed in depth in Chapter 7, traced his ancestry to Nkore, and was a member of the Bacwamba clan.

[7] There is an interesting correspondence between this and other 'first king' myths of central Africa (*cf.* de Maret 2002), who are often said to arrive in a region by crossing a river.

This correlates with Buchanan's reconstruction of the movements of this clan, who she believes adopted a pastoral *embazi* totem (a white cow with distinctive red-brown markings) once they arrived in the cattle-dominated region of Nkore, before heading north to Mwenge. She associates this clan with a period of migration into western Uganda that occurs later than the Basita and Bagabu/Babopi migrations, as illustrated in Figure 2.5 below. As can be seen from this map, several of the Nkore clans also associate themselves with an early migration from the Mount Elgon area (*cf.* also Figure 2.3), and make their way to Mwenge indirectly via Nkore. Another, a Musita called E. Winyi, also told of clans arriving in Mwenge from Nkore:

> "There is a story which says that the Abahinda clan who are Bahuma from Ankole [Nkore], did not know how to work in iron. They intermarried with the Basita, and the children stayed with the clan of their mothers and learned how to work in iron."
>
> (Buchanan 1974a: 102)

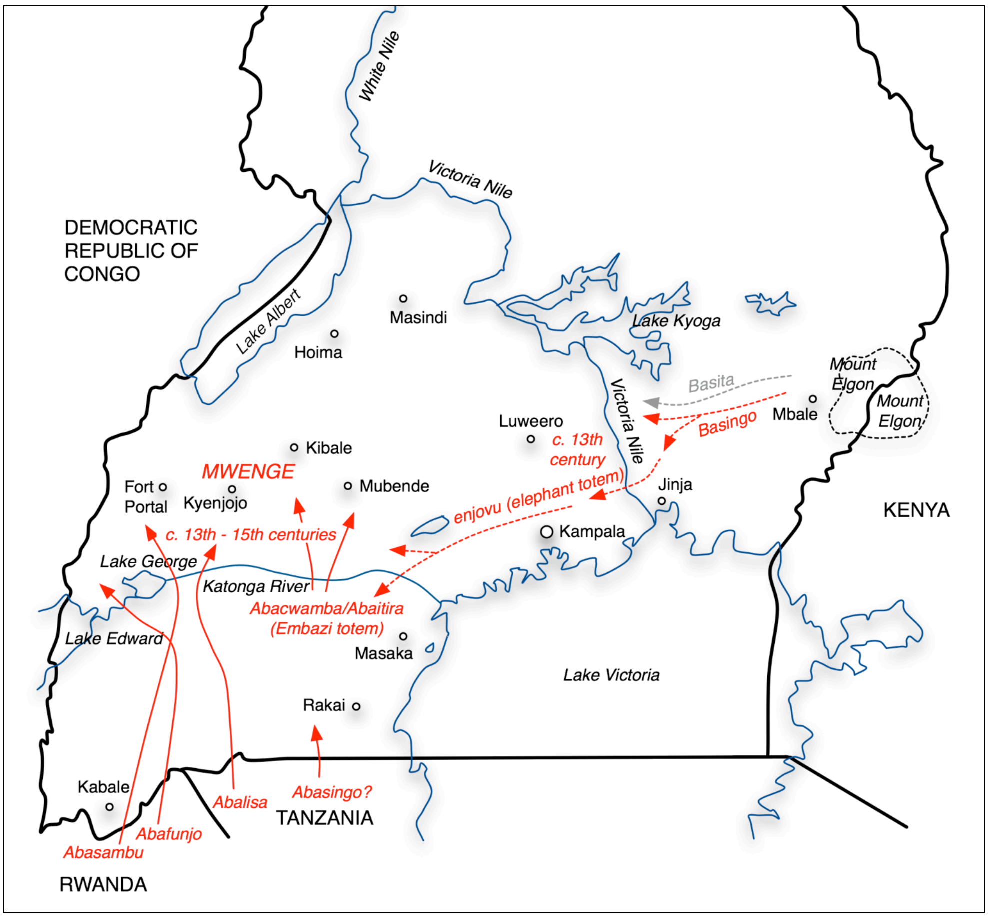


Figure 2.5 Migration routes of Bahuma clans as constructed from clan histories (after Buchanan 1974a: 151)

Buchanan's examination of the movement of Babito-related clans between the fifteenth and sixteenth centuries mentions another ironworking clan, also strongly linked with Mwenge. Buchanan links the Banywagi clan to what she calls the 'Rukidi Tradition' – clans that apparently entered western Uganda from Acholi, through Pawir, in the company of Rukidi. She reports that "part of the Banywagi clan say they accompanied Rukidi south into Kitara. They ultimately settled around Ruhoko in Mwenge saza, where they were "blacksmiths and worked with the Basita"." (Buchanan 1974a: 214). Not only will Ruhoko [Luhoko] feature in several of the coming chapters of this thesis, the quotation she shares from her interview may also be important. Unlike previous discussions of clan-craft associations, which assume that knowledge is held exclusively within clans and protected as such, this comment instead suggests that, at least in some instances, clans may have cooperated by sharing technological knowledge.

Although there are likely to be further smaller Mwenge clans associated with iron production and working (e.g. the Bahati), the most well known for this craft have now been introduced. Although the dates and exact routes are open to debate, it is significant to note that all of these clans appear to comprise some element at least that settles in the Mwenge area: Mwenge does indeed seem to be a particularly important centre for ironworking if these clan histories are taken as read (Robertshaw 1991a). One further clan that is to be mentioned is the Bamoli clan, powerful in Bwera and along the Katonga valley, the leaders of which had a notional and symbolic ironworking role (Lanning 1954; Robertshaw 2010), comparable to many of the ruling factions of Great Lakes kingdoms (*cf.* Célis and Nzikobanyanka 1976; de Maret 1985; Herbert 1993; Reid and MacLean 1995). The clan was also connected with the shrine on Masaka Hill, a place associated with healing and fertility (Sutton 1998: 39), and which was later strongly linked to the Bacwezi.

Buchanan (1974a: 104) briefly touches upon the impact of clan association with technological practice. Recognising that many of her informants recalled a smelting system where miner, smelter and smith were all one person, she indicates that she was struck by the apparent deviation this seemed to suggest from the accounts of the nineteenth century, where specialised occupation groups were repeatedly indicated. In order to explain this discrepancy, she suggests that the accounts she collected could be attributed to a Basita way of smelting: what she terms the 'Mwenge pattern', which she believes "represents not only a chronologically earlier form of technology, but it may suggest different sources as well, (the Basita as opposed to techniques introduced later by the Luo)". She elaborates to say that "the 'Mwenge pattern' survived even after the Babito encouraged greater production and specialization", Although I shall argue later that clan affiliation is indeed likely to have been an influence on technological style (*cf.* Chapters 7 and 8), the implication that this 'Basita' technology and organisation of production would have remained unchanged over the course of many centuries is less probable. Furthermore, it is also unclear as to which nineteenth century accounts of economic specialisation she is referring to. Although she notes Grant's and Pasha's accounts as two of her sources for this (Grant 1864: 295-296 and Schweinfurth *et al.* 1888: 21 respectively), neither directly mention the "threefold division of labor" that she identifies. Her third source is Roscoe (1923: 217-223), who – although he does refer to economic specialisation, with miners and smelters (*bajugusi*), refinery ironworkers (*omusami*) and smiths (*mwesi*) – is writing in the twentieth century and is likely to be referring solely to the smelting he witnessed in Hoima. There is no primary evidence that I can find that this division of technology might have coexisted with other technologies in Mwenge.

ARCHAEOLOGICAL EVIDENCE

As introduced in Chapter 1, the Great Lakes region has often been a focus for discussions about the origins of ironworking in central and eastern Africa. However, western Uganda has tended to fall outside of these debates, as it has as yet produced no early dates for iron production (or other evidence for early iron use). It has been mentioned previously that this area of western Uganda is likely to have been less densely populated than regions further south (and towards Lake Victoria and the Western Highlands) during the Early Iron Age, which may have resulted in different dynamics for this region regarding demand for iron, despite the prolific raw materials found here.

Until now, archaeological investigations into Great Lakes iron production have focused primarily on Rwanda, Burundi and northwest Tanzania (e.g. van Noten 1979, 1983; van Grunderbeek *et al.* 1983, 2001; Schmidt and Childs 1985, 1996; Raymaekers and van Noten 1986; van Grunderbeek 1992; Craddock *et al.* 2007; Humphris 2010), where EIA remains have repeatedly been found. Here, early smelting appears to have often been carried out using conical furnaces made with distinctive decorated bricks, which some have stylistically and technologically linked with the Urewe pottery that dominates this period (e.g. van Grunderbeek *et al.* 2001). Sometimes these furnaces were found to have pits and pots buried beneath them (e.g. van Noten 1983), presumably devices to help the smelt progress smoothly.

The Great Lakes smelting technologies of later periods have been increasingly studied in recent years, both in the same southerly regions as the EIA remains (e.g. Humphris 2010) and, in closer proximity to Bunyoro, around the north and northwest shores of Lake Victoria (e.g. Humphris 2002, 2004; Reid 2003; Reid and Young 2003; Iles 2004; Humphris *et al.* 2009; Humphris and Iles, forthcoming). This has included ethnohistoric study, archaeometallurgical analysis and botanical investigation of two foci of iron smelting activity within the former kingdom of Buganda: one in the western regions, one in the south. Technological approaches in these later periods have been found to be varied, ranging from slag-tapping technologies in Masaaba, eastern Buganda, to smelting in deep furnace pits just 10km away at the site of Kinanisi, as well in the region of Masaka on the western lakeshore. Together these studies will provide some wider regional context to the smelting technologies to be presented later in this thesis.

However, compared to the ethnohistorical and ethnoarchaeological accounts of iron production within western Uganda, the existing body of *archaeological* data regarding iron production is comparatively limited. The evidence so far (not including that collected as part of this research) consists primarily of occasional furnace remains, concentrations of slag blocks, and the remains of mining pits. Added to this are infrequent iron metal finds. Much of the data, often collected during survey targeted towards other archaeological objectives, has the drawback of being unpublished and/or unexplored.

Some of the earliest discussion of activity related to iron production was the documentation of deep 'cylindrical pits' noted in the 1920s and 1950s in Buganda as well as in western Uganda (Wayland 1920; Lanning 1954, 1958, 1979). These were found at Tanda[8] (in Singo), Kako (in Masaka) and Kasasa (in Buddu), as well as in Toro District (specifically a part that is in Mwenge). Although efforts to determine the purpose of these pits were inconclusive, with the pits being found to be sunk through both laterites and kaolin, the pits in Toro (Mwenge) did appear to have been dug for the purposes of mining iron ore. Groups of pits were found at Kisururumi (near Butiti) situated on a southern slope, Rugombe (on the Kampala-Fort Portal road), on a northern slope with several of the pits connected with transverse tunnels, and at Mugangula (11 kilometres to the north of Rugombe). All of these sites (except Mugangula) were relocated during the course of the survey for this research (*cf.* Chapter 4 and Appendix C).

Lanning was of the belief that these pits required such ingenuity and skill to dig that they could not have been originally dug by the "present Bantu-speaking inhabitants of the interlacustrine region" (1979: 147), and instead supposed that the Bacwezi predecessors to the Nyoro must have created them. Even though his interview with the Butiti miners demonstrated that they had *used* the pits as mines, he maintained the unlikely belief – and one based only on presumption – that they must have been reusing pits that had already been dug.

Aside from the presence of these 'mysterious' pits, iron artefacts were encountered during archaeological excavations at some of the sites already mentioned, and furnace remains were also sometimes noted. However, the combination of acidic soils and a wet and warm climate is not conducive to the preservation of iron metal; substantial

[8] These Tanda "death pits" have now entered local folklore as a spiritual place where the evil spirit Walumbe takes refuge (http://zedaway.com/uganda/about_uganda.htm), an interesting aside that indicates the potential shifts in meaning of iron-related sites if local knowledge of features has been forgotten.

erosion in many places has also meant that many furnace remains are likely to have been destroyed. Slag blocks are the most likely remains of iron production to survive in the archaeological record, and are frequently encountered in this region.

Nevertheless, iron objects have been recovered from Ntusi, Bigo and Munsa (Shinnie 1960; Posnansky 1969; Robertshaw 1997; Sutton 1998). At Bigo, many of these objects were just “shapeless agglomerations of rust”, although others were of recognisable items, including bracelets, a spear ferrule, reaping knives, and a number of tanged arrowheads (Posnansky 1969: 141).

Iron objects were also excavated from Kibiro, again including knives and iron bracelets from burial contexts (Connah 1996). Also at Kibiro were two burnt horseshoe-shaped clay features that constituted ‘Site 10’, located near Kigorobya. Although these remained unexcavated, Connah speculated that they could be furnaces for iron smelting, although no slag was found nearby (Connah 1996: 187), and other interpretations are possible. As previously mentioned, a furnace was also excavated at Munsa. This originally buried furnace was radiocarbon dated to around the fourteenth century (1288-1425 AD), and was “tear-drop shaped, about 1 m long, and with clay walls still standing to a height of about 50 cm. It had been broken open at the wider end. There appeared to be a single tuyere port at the opposite, narrow end” (Robertshaw 1997: 14, see Figure 2.6). The large quantity of slag present at the site led excavators to believe that there were further furnaces at Munsa waiting to be discovered.

Iron smelting refuse was also found near Ntusi in an area of haematite ore, although no furnace remains were found (Sutton 1993). Furnaces and accumulations of slag blocks, robust features of past smelting, continue to be regularly found in the wider region (e.g. Robertshaw 1991b; Sutton 2004; Kikonyogo 2010). This provides some indication of the scale and distribution of iron production in the past.

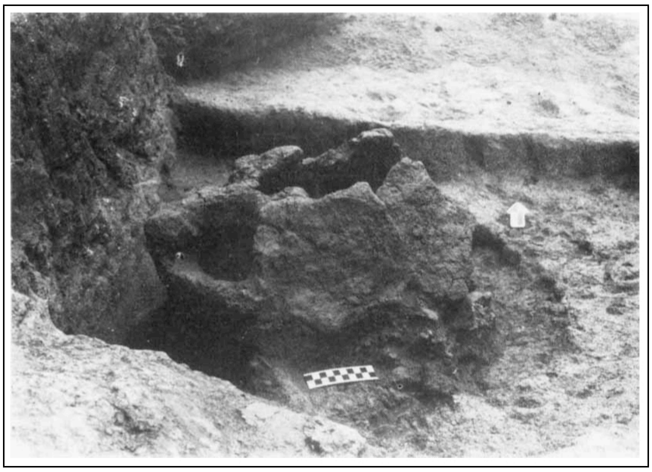


Figure 2.6 Furnace excavated at Munsa. Image taken from Robertshaw 1997, Figure 11. Scale bar is gradated in centimetres

LOCATING IRON PRODUCTION REMAINS IN WESTERN UGANDA

There is a reasonable amount of information to suggest where centres of iron production were located within western Uganda. Childs' ethnographic interviews gave an insight into the organisation of iron production in the Mwenge area, where groups of ironworkers lived near to the raw materials that they exploited (Childs 1998a: 127). This suggests that identifying areas rich in iron ore may be a logical step towards identifying where iron production was focused. Fisher (1911: 3) reports that iron ore was plentiful throughout Bunyoro, but was especially so in the more northerly districts, and this is added to by Emin Pasha's findings, who also found that iron ore was especially rich on the mountains around Kisunga, to the north-east of Masindi (Schweinfurth *et al.* 1888: 122). Masindi itself was built on top of a "bare iron-clay hill", probably laterite (Schweinfurth *et al.* 1888: 21, 521). However, these writers are unlikely to have visited the more southerly regions of western Uganda. The mineshafts found in Mwenge are indicators that iron production *was* occurring on a reasonable scale in this area (Lanning 1954, 1958, 1979; Childs 1998a: 123). Uzoigwe states that iron deposits were found particularly in Bujenje [to the south west of Masindi District], Masindi and Kooki" (Uzoigwe 1979: 34).

Buchanan mentions four areas that were noted in clan histories for being ancient ironworking areas: Mwenge, Bwera, Buddu and Kooki (Buchanan 1974a: 101-102, 219). She also mentions a further ironworking centre in Singo saza, and one called Kasiita near Masindi (Buchanan 1974a: 102, 105-107). Emin Pasha noted that halfway between Londu and Mruli was a station called Kisuga, which was located near bog-iron ore, where iron of a very good quality was smelted and smithed (Schweinfurth *et al.* 1888: 24). As mentioned, clan traditions also strongly link the Basita clan to iron production, particularly in Mwenge, Buddu and Kooki (Buchanan 1974a: 101-102). As such, Basita place names, such as Basita, Kasita or Masita might also identify places where ironworking was carried out. Other place names, such as those from the root for iron ore (e.g. Mbale, Kibale, Butare, Matale and so on) might also be valuable as an indicator.

Iron was a valuable material within western Uganda, yet unlike the southern Great Lakes, evidence for early iron production (i.e. prior to the second millennium AD) has not yet been found. This may be due to a limited population size during this time. In later periods, the production of iron is often posited as instrumental in the creation of local power bases, yet the oral historical records hint that a wide and diverse technological knowledge base grew through the second millennium, with various smelting groups arriving in western Uganda at different times. The movement of these different groups, coming from areas with different raw materials and different socio-political backgrounds presumably had a significant impact on the range of iron production technologies practised in the region.

This summary background chapter has introduced the political, environmental and social settings of the research to follow and the current available sources of information regarding local iron production in the region. Having provided this introductory platform, the information contained within this chapter will be instrumental in the interpretation of the data generated through this research, and will be particularly relevant to the discussions contained in Chapters 7 and 8.

CHAPTER 3

THEORETICAL CONTEXTS: INTERPRETING AFRICAN IRON TECHNOLOGY

Before embarking on any archaeological investigation it is important to explicitly define and acknowledge the theoretical framework within which data will be generated and interpreted. Archaeology is not a "neutral historical science that makes available incontrovertible sociohistorical facts from material remains" (Andah 1995b: 176); archaeological data, incomplete and fragmentary, cannot and does not "speak for itself" (Arnold 1999: 1). Research is guided and data is given meaning in relation to a background context specific to each researcher, formed in part through their upbringing, experiences and cultural belief systems (or 'worldview'), in part through their archaeological education and exposure to (and perhaps conscious adoption of) contemporary archaeological and other sociological theories. This background context is a highly personal (and changeable) response to ideas and concepts, yet explicitly expressing it enables reflection and consideration of one's own personal biases and 'pre-dispositions' (Gardner 2007), and allows future researchers the opportunity to gain a more complete understanding of the basis for the work[1]:

> "…while an archaeologist's ontology enables their imagination, it simultaneously defines the boundaries of enquiry. It shapes what one believes is knowable about the past as well as what questions are worth pursuing."
>
> (Dobres 2010: 104)

[1] Consider Clark's declaration: "For the record, my present bias is that of an archaeological practitioner interested in issues of political economy and social reproduction and of a craftsman with strong interests in technology and manufacturing processes" (Clark 1995: 268). Also, Nic David and Carole Kramer's preface to their ethnoarchaeology textbook: "In terms of theory, CK is more inclined to "naturalist" and ND to "antinaturalist" approaches, but neither is an ideologue. Thus our perspective embraces both the processualism of the New Arch(a)eology and (most) postprocessualism of the 1980s and 1990s" (David and Kramer 2001: xxi-xxii).

With this in mind, this chapter explores the theoretical approaches that have shaped this researcher and thus this research.

Reviews and critiques of the history of archaeological theory in a general sense have been reported and discussed elsewhere in depth (e.g. Hodder 2001; Trigger 2006; Bentley *et al.* 2008; Johnson 2010), and there is not space nor need to discuss the development of all themes here. Whilst accepting that a wide range of theoretical approaches will have influenced the conception and construction of this research, only those considered most directly and immediately relevant will be examined in this chapter.

Within a project such as this, the premise for the work grows from several disciplines, each of which references a number of generations of differing approaches. Specifically, this research falls primarily within three major subject fields: social theories of technology, the application of ethnoarchaeology and ethnohistory to archaeological reconstructions, and the study of African history and archaeology from a Western perspective, which shall be discussed first.

PART ONE: AFRICAN ARCHAEOLOGY

"At this point we leave Africa, not to mention it again. For it is no historical part of the World; it has no movement nor development to exhibit… What we properly understand by Africa, is the Unhistorical, Undeveloped Spirit, still involved in the conditions of mere nature, and which had to be presented here as only on the threshold of the World's History"

(Hegel 1899 [trans. Sibree 2007]: 99)

There are two major challenges in the practice of archaeology within the African continent. The first challenge concerns the place of Africa within its own more recent political history, and how this has impacted upon the conscious or sub-conscious mind of the researcher, African or non-African. Hegel's dismissal of African history (or rather, in his opinion, the lack of one) in his *Philosophy of History* seems astonishing today, but what is more astonishing is that attitudes such as his persisted in playing a significant and ongoing role in the development of archaeological research in the region, arguably into the twenty-first century. The quotation above clearly demonstrates the nineteenth century relationship between Africa and the Western world. Africa was (and unfortunately sometimes still is) regarded as 'the other' – inferior, colonised, exotic: "the concept of Africa is, after all, European in origin" (Rowlands 1995: 262).

This unbalanced relationship has had important ramifications in the implementation of archaeology on the continent, and has been instrumental in producing and promoting doctrines of 'backwardness' and 'primitivism' with regards to African culture, historical or otherwise. Unfortunately, the roots of archaeology took hold and grew amid the expansion of Western colonialism (Holl 1990; Gordon 1999). These forces set the worldwide archaeological agenda for years to come and effectively removed control of the construction of the past (and the shaping of the future) from the hands of those whom it concerned the most (Andah 1995a; Hassan 1999; Gosden 2001; Stahl 2005). Archaeological knowledge was employed to add intellectual authority to the negative hypotheses and stereotypes that were constructed by the colonial powers (Mahachi and Ndoro 1997: 96), and was used as a tool to validate the 'white man's burden' of bringing civilisation to the region (Holl 1990: 300). According to some, the use by archaeologists of terminology such as 'tribe' and 'chiefdom', with their somewhat dubious unilineal evolutionary connotations, keeps Africa in the grip of this damaging dogma (*cf.* Kopytoff 1987; McIntosh 1999): forcing "data into interpretative straitjackets, thereby condemning the past to be forever a ghostly reflection of the ethnographic present" (Robertshaw 1999: 132)[2].

[2] However, such multivariate versions of the past can be controlled to serve a variety of purposes regarding negotiations of political and social power (Pwiti 2000), including positive roles in rebuilding identities after independence (Mitchell 2002: 428), or addressing manipulated historical constructions using tangible evidence (e.g. Giblin 2010).

In sub-Saharan Africa, colonialism (swiftly followed by nationalism) greatly influenced the research agendas that have dominated the archaeological landscape (Hassan 1999; Robertshaw 2003: 149), determining what concepts of culture, civilisation, community and settlement were and are to be considered valid subjects for study (Andah 1995a). Often these have revolved around preoccupations with origins and primitivism, and have born strong racial undertones (de Maret 1990), playing out the suggestion that there is an "inclination to identify superior power, economic, political or military, with moral superiority on an evolutionary scale" (Giddens 1984: 242).

There are countless examples of how these prejudices have been reflected in research and heritage settings. An excellent example is the diorama displays of Khoisan people in the South African Museum in Cape Town. At the beginning of the twentieth century, full body casts were taken from individuals selected to represent the physicality of their 'race'; models made from these casts were subsequently used to illustrate life in the bush from the Late Stone Age to the nineteenth century, bolstering the erroneous view of African life as unchanging and remaining almost primal over thousands of years (*cf.* Lane 1996). These became part of the fabric of society as they were the subject of school visits for generations of (predominantly white) South Africans. After political change in the 1990s and heightened awareness of political rights these were screened off, but not dismantled pending a decision on what to do with them (*cf.* Davison 2001, 2005).

Another example is the investigation of the stone ruins of Great Zimbabwe. On initial 'rediscovery' in the late nineteenth century by Europeans on a hunting trip, the construction of these buildings (considered too advanced for the local Bantu population) was attributed primarily to the Queen of Sheba or King Solomon (Connah 2001) – a hypothesis that stuck in the popular imagination – then later to the Phoenicians (Bent 1902), despite the lack of any supporting evidence. Cecil Rhodes used these theories to justify the presence of his mining company at the site (Ndoro 2005: 28). Early proponents of local indigenous origins for Great Zimbabwe were in the main overlooked for many years (MacIver 1905; Caton-Thompson 1929). Even then, the more significant questions of what the ruins meant in social or economic terms were ignored in lieu of the dominant themes favoured by Western researchers – origins and chronology (Mahachi and Ndoro 1997; Meskell 2002). The more socially-oriented topics, of greater relevance to local histories, were not addressed until the second half of the twentieth century (Connah 2001). Even in the 1980s, guidebooks to the site contained no mention of its African origins (Ndoro 1994: 33).

Together these examples illustrate the dichotomy that dogged early research into Africa's past: 'native' Africa was considered static, primitive, underachieving, evolutionarily inferior; any discovery that impressed colonial eyes was assumed to be derived from an external source:

> "The civilizations of Africa are the civilizations of the Hamites, its history the record of these peoples and of their interaction with the two other African stocks, the Negro and the Bushman ... The incoming Hamites were pastoral 'Europeans' – arriving wave after wave – better armed as well as quicker witted than the dark agricultural Negroes."
>
> (Seligman 1930: 96)

This denial of a proud indigenous past served to justify the exploitation of local communities and the expropriation of their land by the colonisers (Robertshaw 1990: 84; see also Esterhuysen 2000). Moreover, these assumptions also influenced those considering the origins of ironworking on the continent. As briefly touched upon in the preceding chapter, the overriding belief was that the highly skilled technology of ironworking was introduced to Africans, not invented by them (Alpern 2005): it was beyond local capabilities to develop such a skill. Ironworking was believed (on the basis of no positive evidence) to have diffused from the Near East into Meroë, Sudan, and into western Africa from Carthage (Woodhouse 1998: 160), from where the technology was able to dissipate through the rest of the continent as part of the 'Bantu expansion' (Huffman 1989). Although these theories have been disrupted by the generation of very early dates for iron production in western and eastern Africa, and the wide variability in smelting practice across the continent (e.g. Cline 1937), there is as yet (and is unlikely to be) no resolution of this question (*cf.* Killick 2004a, 2009; Alpern 2005). Nevertheless, this early bias has pervaded current research into iron production, and there remains a strong desire to identify the *earliest* examples of smelting. Research has therefore been dominated by investigations into early iron production within agricultural contexts, whilst comparatively little research has been carried out into the iron technologies of later periods (although see Humphris 2004, 2010; Humphris and Iles, forthcoming), with almost nothing on the iron technologies of pastoralist communities (although see Iles 2006; Iles and Martinón-Torres 2009).

The second challenge facing African archaeology concerns the ability of non-African researchers – which currently make up the bulk of researchers working within the continent (Schmidt 1995: 123; Stahl 2005: 5) – to *effectively* understand or interpret the history of Africa, but more importantly, the history of Africans. There has been a tendency to address the archaeology of Africa in universalist terms, using Eurocentric models and methods "that tend to obscure rather than illuminate their subject matters" (Andah 1995b: 150) – "the social theories used to explain variability and change in African human behaviours … have usually been drawn from European experience" (Andah 1995a: 105; Insoll 2004).

There are several prevailing Eurasian models with which the African past seems to be at odds. One example is the (now mostly outmoded) application of unilineal evolution, where social complexity is seen to develop from bands to tribes to chiefdoms to states (e.g. Service 1962). This emphasis on 'progression' is thought to have derived from a western preoccupation with typology rather than relationship, as well as the Judeo-Christian tradition of the nineteenth century (Shennan 1993). Yet we see across Africa "numerous and contemporary polities at different levels of scale and integration" (Robertshaw 1999: 132), seemingly challenging this structure. Instead, "dispersal and renewal of people and power appear to have been signatures of the Great Lakes region, indicating thus the frustration of pursuing purely evolutionist paradigms for the progress of political centralisation" (Schoenbrun 1999: 137).

Other examples more specifically concern the study of iron production. The early dates for ironworking in central and eastern Africa suggest that there was no preceding Bronze Age in sub-Saharan Africa (van der Merwe 1980: 497), challenging Thomsen's Three Age Model (Heizer 1962). On a different scale, research in central Kenya revealed a smelting system practiced by pastoralist ironworkers on the Laikipia

Plateau resulting in slag with five (not three) major components: titania, lime, iron oxide, alumina and silica (Iles and Martinón-Torres 2009). This meant that the operating parameters of these smelts could not be readily interpreted within the usual Eurasian-derived models, which generally assume a fayalitic (rather than ulvitic) slag. The tendency to examine African archaeology within the framework of Eurocentric models can be a hindrance at best, and a constraint to our understanding of African cultural history at worst (Andah 1995a).

An even more important problem according to Andah, is that the meeting between European and African cultures is

> "a meeting between worlds in which there are alternative viewpoints regarding the reason for living, the objective and subjective aspects of living and life, and evaluation of these from different standpoints. Each has its own knowledge system, which incorporates clear rules guiding individuals and social conduct and action, and a pool of cultural experience, which embodies the actual operation, or rather, translation, of this knowledge system into practical conduct and action."
>
> (Andah 1995a: 103)

Archaeology as we currently know it has grown from a primarily Western mindset, and continues to grow within a capitalist, industrialist and individualist world (Foucault 1969; Shennan 1999; Thomas 2004; Dobres 2010); as archaeologists we inescapably interpret the past through the eyes and experience of the present (Drewal 1996: 110). Concepts of culture, time, values, knowledge and history can vary greatly from those of the western researcher, but in these circumstances, the privileged researcher – coming from a 'scientific' culture and background (*cf.* Jones 2002) – chooses what to record and what to discard (Grosz-Ngate 1988). Recognising these potential biases is an important first step, as it is only by highlighting the assumptions that are made that they can be challenged and, if necessary, changed.

PART TWO: THEORY OF TECHNOLOGY

At this point, our discussion of African archaeological theory merges with a discussion of technological theory. Until recently, theory of technology has been grounded within what Pfaffenberger (1992) calls the Standard View, as derived from the Standard View of Science (Mulkay 1978), both of which developed within distinctive economic, ideological, rationalist and materialist conditions. This "modern and technocentric" – and Andah might say *ethnocentric* – view sees technology as comprising "materially grounded pragmatic behaviors separate from, underlying, and impinging upon politics, social organization, beliefs, and value systems" (Dobres 2000: 10). Is this the same view that an African smelter, past or present, would recognise? If we apply only this knowledge base to our research strategy, will we be able to fully and successfully understand an example of iron production that operates or operated within an alternative epistemological context?

Fortunately, theories and frameworks regarding the concept of technology have changed drastically in recent years (Sillar and Tite 2000). Ethnoarchaeology, with the advantage of witnessing social and ideological aspects of technological systems in practice (Childs 1994: 8), has been able to reveal how the two spheres of the material/technical and the social/ideological/symbolic should not and cannot be disassociated. Rather than seeing technology from a "mechanistic perspective", research began to explore the relationship between "cultural paradigms, mental constructs, shared world views … and material cultural practice" (Dobres and Hoffman 1999: 1, 5; e.g. Lechtman 1977, 1984; Lemonnier 1986). By approaching technology in this way, an examination of technology became an examination of "past social relationships and how they were forged, mediated, and made meaningful during the everyday practice of material culture production" (Dobres 2000: 1; see also Hegmon 1998; Costin 2005). The study of material transformation is revealed as a tool not only to investigate the development of a technology, but also the history of a group of people (Gosselain 1992; O'Brien and Leonard 2001). However, in order for this to happen, a suitable theoretical approach must be employed.

This relationship between the technical and the social has been most effectively demonstrated in what has become known as the Science vs. Magic debate in examinations of African iron production. In Western thinking, the 'mind' (magic) and the 'matter' (science) tend to be regarded as separate and opposing entities (Horton 1993: 227)[3]. However, ethnoarchaeological examples of African iron production showed that problem solving was commonly approached with a combination of ritual and technical methodologies (de Barros 2000: 166), with magic seen as a means by which to control and understand the otherwise uncontrollable (Collett 1993; Herbert 1993). Structured according to specific worldviews, the resulting technological processes in these instances are often expressed in terms of analogies with bodily and social processes (Eliade 1962; Childs and Killick 1993: 325; Helms 1993: 18): reproduction and fertility – social, human and technological.

In the case of Fipa smelters, the furnace is seen as analogous to a bride; if the smelters have sex during the period of the smelt, they are in essence committing adultery against their furnace wife, and the bloom and the success of the smelt may be compromised. Adultery amongst the Fipa is seen as a dangerous act that may result in problems with fertility or death at childbirth, and as such there may be a link between these taboos, the furnace symbolism and the wider Fipa belief system: an insertion of "social and cosmological ideas into the technological activities" (Barndon 1996: 66, 68-71). In the case of the Phoka of Malawi, 58 different types of specialised medicine were seen to be involved in preparing for a smelt, many buried in a ritual pit beneath the furnace (van der Merwe and Avery 1987). In a general sense, these often correlate with medicines used in local healing, including those for fertility, those to protect against witchcraft, and those that impart certain qualities, such as strength and toughness (Schmidt and Mapunda 1997) – qualities that are hoped for in a furnace as much as they are in a person, again anthropomorphising the furnace.

Far from being a subsidiary or supplementary technology to the technical process, such ritual and symbolism often involves a large amount of knowledge and requires a

[3] See also Richard Dawkin's *The God Delusion* (2006), and surrounding media discussion, for the current 'Science vs. God' debate raging in the West, which derives from a very similar sentiment.

substantial input of energy, time and resources. Such technology is an integral and essential part of the process: the 'technical' and the 'ritual' are not mutually exclusive categories. Van der Merwe and Avery (1987: 144) saw that "iron smelting could not be conducted without it [i.e. magic]"; this was similarly expressed by Rowlands and Warnier (1993: 537) as "pure and simple production requirements". The symbolism attached to African smelting tends to be discussed in functional terms; that is to say, it is employed to ensure the productivity of the smelt, as well as to ensure the safety of the smelters (Schmidt and Mapunda 1997). Through these and similar examples, technology has been revealed as a *socio*technical system (Pfaffenberger 1992). Without an analytical and integrated focus on these interwoven elements, an important part of technology would be lost to researchers.

Because of this demonstrated link between technological behaviour and worldview, it is understood that by attempting to infer the *intent* expressed through the material choices that technological actors in the past made, we can begin to explore how past society was organised and structured. One methodology that has been developed in order to explore choice more carefully and thoroughly has been the notion of *chaîne opératoire* or 'operational sequences' (Leroi-Gourhan 1945; 1964; also *cf.* Lemonnier 1992; Schlanger 1994; Dobres 2000; Ottaway 2001). This was drawn from Mauss' thoughts on *enchaînements organiques* (Mauss 1935) – repetitive gestures of everyday life that are subconsciously learned from community membership, which he saw to embody identity. Within a technological context, the chain of events contained within a *chaîne opératoire* inherently includes the technical and the social, linking the tangible and the intangible. They articulate a dynamic web of actions and interactions, cognitive processes and relationships that have to come together to transform material and society (Dobres 1999).

At the heart of all of these activities are communities of varying sizes and relationships that are seen to instil a predictable and measurable order on the choices made at each stage of the *chaîne opératoire*: society as expressed through the process and therefore through the material. Yet also relevant to these discussions are individuals, a much more complex category to explore archaeologically (Shennan 1991: 199). Although "society wrote its identity upon the archaeological record through the activity of its members", "societies are treated as if they were real things which can be studied independently of the agencies which inhabited them" (Barrett 2001: 147). Our referent now becomes the 'agent' – individuals, as self-aware humans, who actively transform their world (Gardner 2008).

This notion of agency grew in the 1980s as a critique of the preceding culture-historical and processualist approaches that placed a disproportionate emphasis on cultural or environmental factors as the determinant of human action, rather than considering the individuals' interpretation of events. The application of such an approach requires a careful balancing of the relationship between the agent and the structure within which that agent operates, i.e. society (Gardner 2008). Contrasting with Childe's belief that an individual's behaviour is *learnt* from society (Childe 1956), this recognises that individuals actively *make* society (Barrett 2001). Yet agency does not deny the role of 'the structure', society: it is in the *relationships* between these subjects that agency is manifest (Dobres 2000). That is to say, "the study of agency is not the study of individuals *per se*", but rather how agency is formed in certain contexts (Barrett 2000: 61)[4].

However, whilst the agent is recognised in ethnoarchaeological examinations of iron production (e.g. Schmidt 1997; Barndon 2004), agency is not as widely considered in archaeological examinations. One problem is that more often than not the only actions (of individuals) that can be explored in the archaeological record are those that are widely repeated, that is to say, shared (Dornan 2002: 312). Yet, in a technological context, careful examination of the *chaînes opératoires* used to create objects or materials can reveal how people have chosen to materialise their agency, and can expose the ways in which craftspeople relate to established traditions (Gardner 2008). This might be expressed through change, variation and innovation (*cf.* van der Leeuw and Torrence 1989; Charlton *et al.* 2010). However, for technological change to occur a

[4] The concept of agency was also a significant influence in postcolonial archaeology. Colonisation began to be seen not just as a force of power over a static culture, with local cultures instead developing from these influences into something new again (Gosden 2001: 243).

combination of individual innovators (or indeed, inventors) *and* a society receptive to change is needed.

The notion of the individual's relationship with established traditions is one I find particularly interesting. On the one hand technology is accepted to be dynamic and changing, but there remains a presumption that the social/ritual/symbolic aspects of technology are much more static and entrenched than technical ones (e.g. Schmidt 1997a: 60) – despite some evidence to the contrary (e.g. Herbert 1993: 28-29) – with metalworkers assumed to be unable to assert their agency over these aspects of technology. This concept raises a large set of questions about technological operation in each context. If we assume that an individual is inherently self-interested, where does this self-interest lie? Does it emerge in innovation and experimentation? Or does it manifest in characteristics such as loyalty, duty and conforming to social norms, i.e. *actively* maintaining established traditions (Shennan 1991: 200)?

Isolating agency through variation might be a particularly pertinent issue within African contexts. Kopytoff (1987: 6-7) suggests that movement within African societies was common, both in terms of frequent small-scale movement (which form the basis of his 'Frontier' model) and large-scale diaspora (e.g. relating to trading, military or pastoralist movements); Charsley's experience of localised mobility has been outlined in the previous chapter. This results in highly diverse urban centres. Fletcher (1998: 110) believes that a high level of mobility "continually alters both the membership of a resident locality and the *continuity and complexity of information dispersal* through that locality" (my emphasis), which reduces the level of 'detailed familiarity' with "idiosyncratic local social practice". In other words, as new actors enter the mix, new information is continually being shared in new ways. With a diverse range of technological systems in place within an area, does this lead to an *increased* tendency towards change within 'established traditions' (both technical and social), or a more entrenched *protection* of techniques? Processes of knowledge transmission, selection of technological traits and innovation are embodied in the style and function of artefacts and technologies (Cochrane 2001: 196): in the first such scenario, this could potentially lead to a wide range of variation, something that is definitely present in the "mind-boggling variety" of African iron production technologies (Childs and Herbert 2005: 284). Others present a different solution. Mapunda (2010: 217) proposes that the multiplicity of iron technologies throughout the continent is attributable to the secrecy maintained within each smelting group. Young smelters, leaving their mentors to forge "their own career in metallurgy", found themselves equipped with only partial knowledge of the complete technological systems they had previously taken part in; working without guidance, they were forced to make the process their own. Both possibilities present intriguing suggestions as to the outcomes of different forms of knowledge transmission and innovation.

PART THREE: ETHNOARCHAEOLOGICAL AND ETHNOHISTORICAL RESOURCES

Many of the theoretical insights that have been described in the previous sections have been stimulated, or at least encouraged, by a prolific and growing volume of ethnographic, ethnoarchaeological and ethnohistoric data regarding technology. Archaeological interpretation rests ultimately on the interpretation of material remains within a personal frame of reference to parallels in the present; such inherent analogical reasoning underpins *all* archaeological interpretation (David and Kramer 2001; Wylie 2002; Johnson 2010). Explicit and implicit reference to a range of ethnographic information, whether gathered formally or acquired informally, plays a primary role in the formation of our understanding of the past.

With the development of ethnoarchaeology – a discipline that employs a combination of ethnographic and archaeological methodologies to generate data of improved relevance to archaeological interpretation (David 1992) – so also developed an increasing awareness of the necessity to consolidate all aspects of the technological processes under examination: social, technical and ideological (David and Kramer 2001). In recent research, the integration of ethnoarchaeology, materials science, ethnohistory, experimental archaeology and archaeological excavation (e.g. David *et al.* 1989; Hosler 1994; Schmidt 1997; Dupré and Pinçon 1997) has enabled wider-reaching questions to be addressed of archaeometallurgical remains. Such an interdisciplinary approach, using a range of information regarding the present, can contribute to building a more complete picture of the past, revealing metallurgy in its wider social context.

There has been much theoretical discussion regarding what is the most effective and responsible way to apply ethnoarchaeological data to archaeological remains in order to maximise our understanding of the past (David and Kramer 2001; Lane 2006; Iles and Childs, forthcoming). Returning to the first section of this chapter, it is recognised that relying too heavily on ethnographic information to interpret remains of the distant past could reinforce the erroneous belief of the primitive and unchanging nature of Africa's cultural histories. We can reliably assert that "every living community is in the process of continuous change with respect to the materials which it utilizes" (Ascher 1961: 324); although ethnoarchaeology can help us to begin to understand these processes of change, stimulating the development of archaeological theory, it causes problems when considering when and how to use ethnoarchaeological data within archaeological problem solving. Ethnohistorical, ethnoarchaeological and ethnographic sources are situated within complex historical, social, economic and political contexts; data derived from these sources are unable to provide 'timeless' technological analogies for past metallurgical practice (Killick 2009). So how useful and appropriate can ethnographic analogy really be?

There are several highly valuable lessons that have been learnt from the consideration of the ethnographic, ethnoarchaeological and ethnohistoric records as a whole. Together, they have proved key in demonstrating just how much variation is possible within metallurgical practice and even within a single technological process (*cf.* for example Cline 1937), a realisation which has warned against the projecting of any one single example of metalworking method onto the past (*cf.* Rowlands 1971). One further benefit of referring to ethnoarchaeological resources is the (at least partial) dilution of the implicit ethnocentric preconceptions of an individual researcher (Gould

1978). An archaeometallurgist will automatically draw upon their personal experiences of metallurgy; by interacting with a variety of modern practitioners and historical sources, their perspective will be broadened. Furthermore, "[Western] archaeologists working among non-Western peoples often do not know how those people understand their own pasts" (Ellison 1996: 5). A greater level of interaction with and learning from local people through ethnographic and ethnoarchaeological research can help gain a more considered understanding of the history of any region.

However, in a more specific sense, using direct ethnoarchaeological analogy to interpret archaeological remains will always be problematic. Scholars in the nineteenth and early twentieth centuries, when ideas of unilineal social evolution were popular (e.g. Spenser 1863; Lubbock 1865; Childe 1930, 1940), were content to draw explicit parallels between contemporary, small-scale, so-called 'primitive' societies and those of Eurasian prehistory. Observations of indigenous communities in, for example, sub-Saharan Africa were often fed into interpretations of prehistoric remains in Britain and vice versa, a trend that continues to influence modern research (e.g. Renfrew 1973; Giles 2007). Such uncritical application of ethnographic analogy, founded squarely in the prejudices and stereotypes described in Part One, are not useful in trying to decipher how peoples' lives in the past were organised, or indeed, within the postcolonial framework of the modern world.

Demonstrating a cultural continuum between a past and present community can help reduce the problems of the applicability of such data, but cannot remove them entirely, especially if we accept the premise: "the past is a foreign country: they do things differently there" (Hartley 1953: 1). Even in the past few centuries, large shifts in social organisation have been recognised across the globe: can the cultural identities and practices of postcolonial communities provide relevant analogues for their precolonial predecessors (Andah 1995a: 101)? Recent years have seen populations physically removed from areas where they lived and alienated from their heritage and pasts (Pwiti and Ndoro 1999; Mitchell 2002; Ndoro 2005); similar cultural and political disruptions have surely been commonplace within the long-term histories of most regions.

There are also notable problems with the *recording* of ethnographic or ethnoarchaeological data. Examples of iron smelting make up by far the largest component of the body of ethnoarchaeological work regarding metallurgy, yet very few ethnoarchaeologists have been able to observe an iron smelt "carried out in earnest to obtain iron" (David and Kramer 2001: 335; David 2001). The assumption must be that the methodologies used will not be exactly the same as if the smelt was undertaken for local economic production. Furthermore, many comprise reconstructions of smelting technologies that were abandoned decades before (e.g. Echard 1968; Saltman *et al.* 1986; David *et al.* 1989; Huysecom and Agustoni 1997); how reliable can memories of these processes be, and how much trial and error is employed without the researchers knowledge? Master smelters may also choose not to reveal all of the rituals and secret knowledge that would otherwise constitute a major part of their smelts (Herbert 1993: 16-17; see also MacLean 1996: 29).

There are further factors that may influence the collection of ethnoarchaeological data. Value-laden agendas and the hidden biases of researchers will influence what ethnoarchaeological questions are asked, how they are asked, and to whom they are directed. The unspoken agendas of informants are also relevant. Whether a researcher is foreign or local, male or female, old or young can influence what the informant chooses to disclose (*cf.* Iles and Childs, forthcoming). Being explicit about the identity of researcher and informant, and about the methodology and the context of the research can assist with future assessments of the work.

Yet despite the issues that surround the acquisition and application of ethnographic and ethnoarchaeological resources, they provide a valuable research resource, greatly enriching our interpretations and understandings of cultural history, especially when combined with archival and oral histories (Hassan 1999). Unfortunately, time is running out to be able to interact with many of those who have memories of living 'traditional' metallurgical practices, as these industries retreat into a more and more distant past and the practitioners pass away (Childs and Killick 1993; David 2001).

All of the above theoretical concepts have played a role in this research, whether in the formulation of the research questions, the design and implementation of the research strategy or the interpretation of the resulting data. Although many questions have been raised through a consideration of these topics, by approaching them with a critical theoretical awareness, I hope that my methods and conclusions are demonstrated to be appropriate and valid.

CHAPTER 4

APPLIED METHODOLOGY

In order to examine the research questions as set out in the first chapter of this thesis, a methodology had to be formulated in order to produce appropriate and reliable data. This methodology had to fulfil three explicit initial aims. First, intensive survey was to be undertaken to locate sites relating to iron production in Mwenge. Second, a representative selection of these sites was to be excavated in order to generate contextual data and samples suitable for archaeometallurgical analysis. Third, appropriate archaeometric analysis was to be undertaken on these remains, to generate data by which the smelting technologies employed at the excavated sites could be reconstructed. All of these endeavours were planned in such a way as to generate the *maximum* possible data return given the available resources. However, as it is never realistic to create a complete reconstruction of the archaeological record, a sampling strategy also had to be employed at various stages at the research to enable the formulation of a suitable dataset from which to work.

The approaches chosen to address these aims – archaeological and archaeometallurgical – are outlined below. As is always the case, these choices were governed not only by the applicability of certain approaches to the project. The time scale and budget dedicated to this research, as well as the accessibility of certain laboratory and analytical procedures at the UCL Institute of Archaeology, also influenced the methods that were decided upon. Practical considerations in Uganda also had an impact upon the planning and implementation of the fieldwork. However, the methodology described below was founded upon my experiences developing and executing field research in Uganda, Kenya and Rwanda since 2003, which have given me a sound basis on which to build an appropriate and effective research strategy.

PART ONE: THE FIELDWORK

In a region where comparatively little archaeological research has been undertaken to date (*cf.* Chapter 2), primary fieldwork was necessary in order to generate data by which to examine past technological practice, and technological variation within, and between, precolonial smelting groups in Mwenge. This newly generated data could then be evaluated in conjunction with the existing ethnographic and ethnohistorical data, facilitating discussion of the relationships of these past craft specialists and iron production industries with the larger social and political spheres within which they operated. Both survey and excavation needed to be employed to locate new sites and generate archaeological material.

PRELIMINARY PLANNING

One of the initial tasks of the research was to determine the geographical areas to be covered by the fieldwork. Oral histories and ethnohistorical accounts, together with information from previous archaeological research, plus information concerning clan histories and the origins of local place names, were examined in order to demarcate specific areas that were likely to have once constituted centres for past iron production (e.g. Roscoe 1923; Buchanan 1974a; Tantala 1989; P. Robertshaw 1991a, 1991b, 1994, pers. comm. 2007; Childs 2000; J. Sutton pers. comm. 2006). Detailed background information obtained from these sources (*cf.* Chapter 2) suggested that iron production activity was centred round the locales of Masindi, Kooki (in the district of Rakai) and Mwenge (in the district of Kyenjojo), and subsequently three survey zones were defined in these areas, as shown below in Figure 4.1. As Mwenge was to be the central focus of this research, the largest area to be examined was demarcated for survey in this region, and the longest stretch of time was allocated to it.

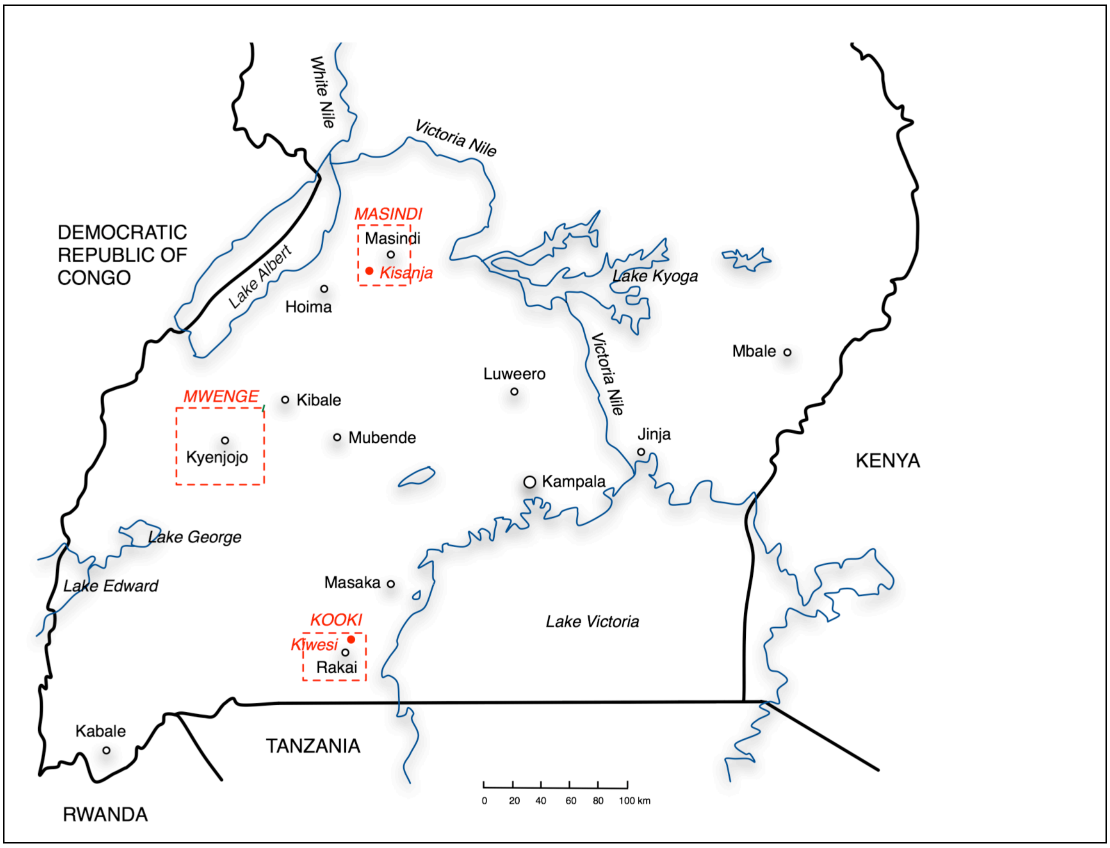


Figure 4.1 Map showing the three survey zones demarcated for the 2007 survey (indicated by the red dotted lines). The sites of Kisengya and Kiwesi are also marked

The Mwenge survey zone in Kyenjojo District covered an area of about 40 by 40km, encompassing part of six of the eight sub-counties within the county of Mwenge: Katooke, Kyarusozi, Butiiti, Bugaaki, Nyantungo and Kihuura (Figure 4.2). Survey spanned from Kagorogoro in the west to Matiri in the east, and from Mirambi in the north to Rweitengya in the south (using 1:50000 maps from the Uganda Department of Lands and Survey, numbered 57/4, 57/1, 56/4, 57/3).

The landscape typical to Mwenge comprises stretches of gentle hills interspersed with patches of marshland and occasional pockets of dense forest, along with modern tree plantations for commercial logging in the northern and central-west areas. Extensive tea estates cover some of the north and west, which severely restricted the ground visibility in these areas (Figure 4.3). The protected forest reserves of Matiri and Kibale denoted the limits of the survey zone to the east and west respectively.

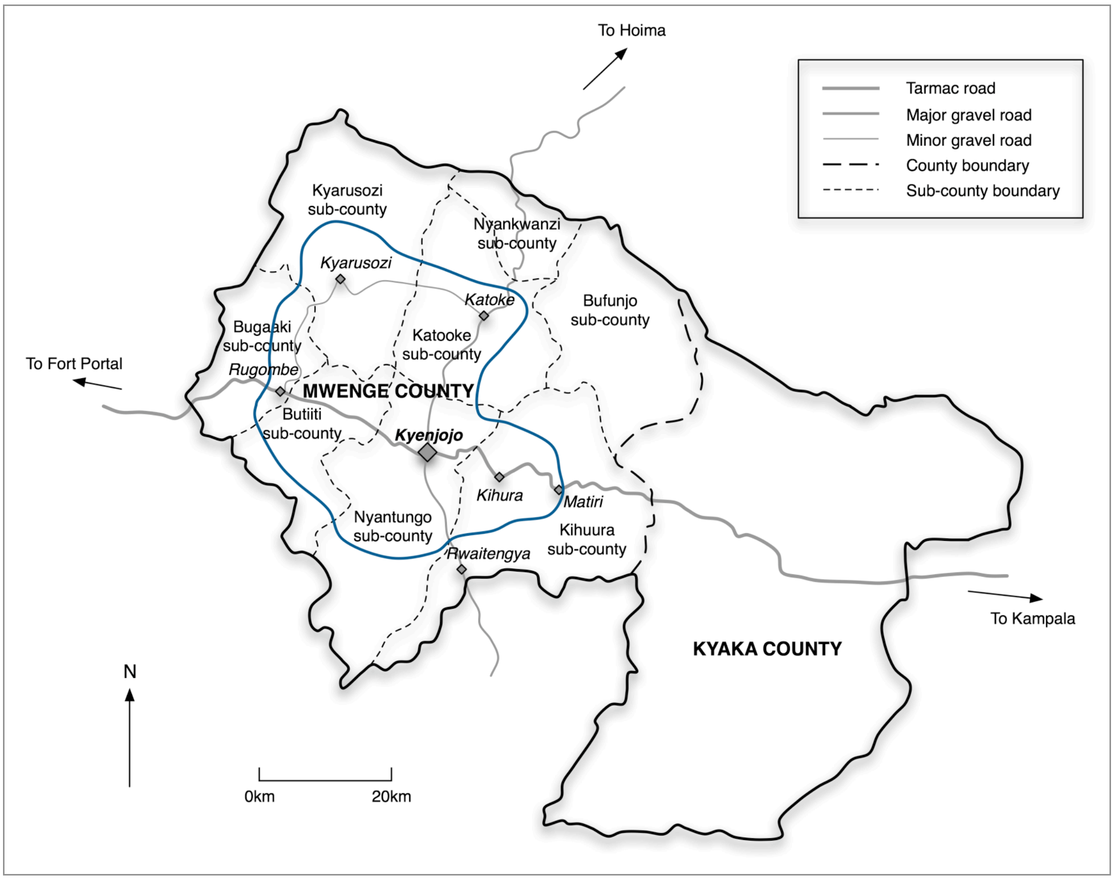


Figure 4.2 Map of Kyenjojo District (adapted from Rwabwogo 2005), with the approximate Mwenge survey zone shown depicted as a blue line

Figure 4.3 Google Earth image of the area immediately to the west of the Mwenge survey zone, showing coverage of tea plantations (to the left of the picture) and pockets of dense forest (in the top right corner), interspersed with fingers of marshy land – features which severely hampered survey

As the archaeological potential of Mwenge could not be guaranteed before the fieldwork was embarked upon, smaller pilot surveys were also planned within Kooki and Masindi. These would not only ground truth the collected ethnohistorical information, but would provide a backup plan if data was not forthcoming in Mwenge. Furthermore, if all three areas proved fruitful, this would provide some extent of regional comparison. However, considering the particularly high density of data that was generated from Mwenge alone, the survey data from the supplementary survey zones, and the excavated sites of Kiwesi (Rakai District) and Kisengya (Masindi District) are only presented briefly in Appendices A and B (see also Iles 2009a).

FIELD METHODOLOGY

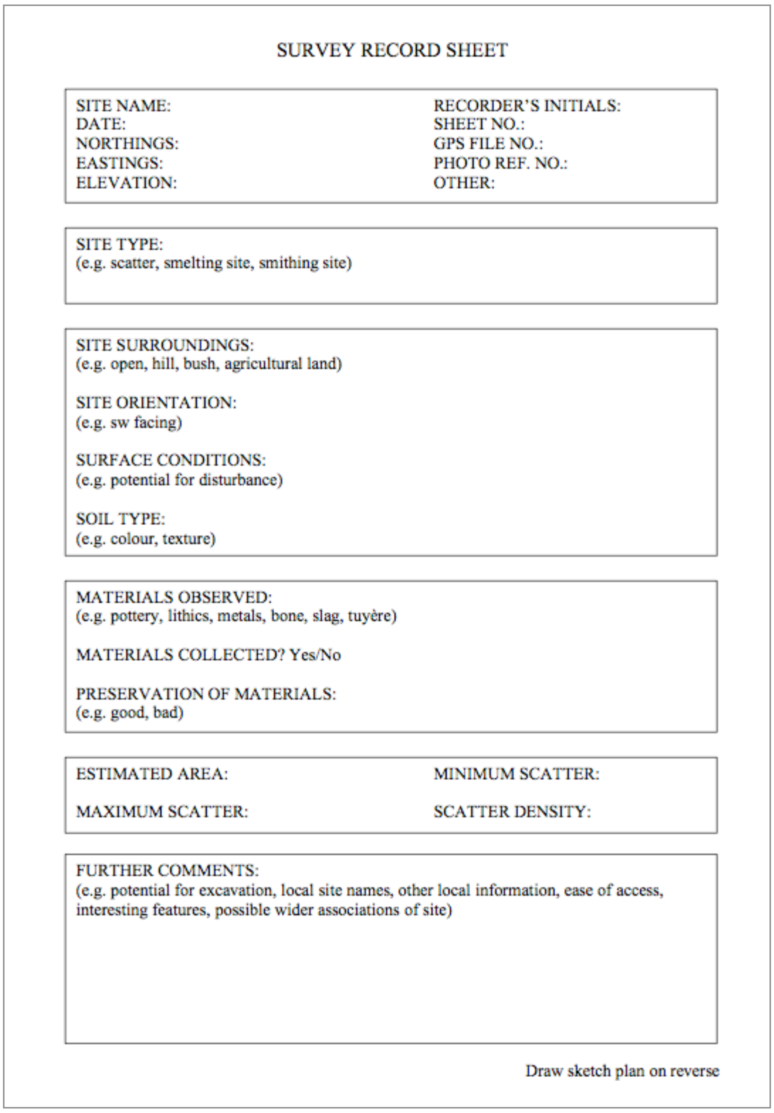
APPLIED SURVEY METHODOLOGY

It was important to develop a survey strategy that would be effective in locating sites within such densely vegetated and farmed environments (*cf.* Figure 4.4), whilst remaining sympathetic to the interests of local communities. Land-ownership issues are a major concern for many local people, and strangers walking across the land are often regarded as highly suspicious, and potentially a threat to the land itself. Learning from the survey-feasibility studies that had been carried out in western Uganda by Peter Robertshaw in the early 1990s (Robertshaw 1991a, 1994), which found strict transect survey to be impractical in these environments, as well as from the recent survey carried out in nearby Rwanda by John Giblin (Giblin 2008, 2010), a joint strategy was decided upon, combining a systematic, road-, track- and path-based survey with a more flexible, informant-led approach. These two complementary systems provided the most comprehensive cover possible for such an area, whilst maintaining maximum involvement of local residents. The fieldwork team was large enough that two survey teams were in operation throughout the survey period. A diary of day-by-day activity and notes was kept throughout the duration of the survey.

Figure 4.4 Typical landscape in central Mwenge: rolling hills covered by near continuous banana and cassava plantations, interspersed with occasional open fields. The central hill in the background of the photograph is commercially forested with pine, and contrasts with the pockets of native forest trees that can be seen in front of it

Major and minor roads and paths within the survey areas were traversed by a survey team, as were areas of open land that were adjacent to a road or pathway. Exposed land and road cuttings were inspected for archaeological remains (Figure 4.5), and informal 'interviews' were carried out at habitation centres and when people were encountered on the road to enquire whether there were any known concentrations of slag (*inyanga, ibyanga, byenga)* or old or unusual pottery in the vicinity. Frequently, this would result in us being accompanied to a nearby site. Once identified, each site was allocated a site code and a GPS location, and detailed information was recorded regarding the visible archaeological remains together with any additional local information about the site (Figure 4.6). Although this survey strategy was highly effective in locating new sites, it importantly does *not* profess to present a dataset that is representative of the *patterns* of past site location; the main aim of this survey was to identify new sites related to iron production with high potential for excavation in order to address the research goals of this project. Copies of all survey data are held at the Uganda Museum, Kampala (*cf.* Appendix C and Iles 2009a).

Figure 4.5 Walking survey in progress, examining an exposed road cut



SURVEY RECORD SHEET

SITE NAME:	RECORDER'S INITIALS:
DATE:	SHEET NO.:
NORTHINGS:	GPS FILE NO.:
EASTINGS:	PHOTO REF. NO.:
ELEVATION:	OTHER:

SITE TYPE:
(e.g. scatter, smelting site, smithing site)

SITE SURROUNDINGS:
(e.g. open, hill, bush, agricultural land)

SITE ORIENTATION:
(e.g. sw facing)

SURFACE CONDITIONS:
(e.g. potential for disturbance)

SOIL TYPE:
(e.g. colour, texture)

MATERIALS OBSERVED:
(e.g. pottery, lithics, metals, bone, slag, tuyère)

MATERIALS COLLECTED? Yes/No

PRESERVATION OF MATERIALS:
(e.g. good, bad)

ESTIMATED AREA:	MINIMUM SCATTER:
MAXIMUM SCATTER:	SCATTER DENSITY:

FURTHER COMMENTS:
(e.g. potential for excavation, local site names, other local information, ease of access, interesting features, possible wider associations of site)

Draw sketch plan on reverse

Figure 4.6 Survey recording sheet used during the 2007 survey

MWENGE SURVEY RESULTS

As expected, the most commonly encountered sites in each survey zone were slag scatters, due first to the high durability of slag as an archaeological material, but also to the fact that it often presents itself as a nuisance to local farmers when digging their fields. However, a number of sites were also located that included the remains of eroded furnace bases, and several sites were located that comprised iron-ore mining shafts (locally called *enambo*).

One hundred and twenty sites were found in this survey zone (Figure 4.7, and Appendix C), and the greatest concentration of sites appeared to cluster around the modern town of Butiti. Eighty-five were characterised by significant accumulations of large slag blocks; twenty of these also included visible remains of iron smelting furnaces. Sixteen sites comprised areas of mining pits, whereas others comprised smaller scatters of slag fragments[1].

Figure 4.7 Sites found during the 2007 fieldwork in Mwenge (yellow lines mark roads)

[1] Basic information regarding these sites (location, prominent iron-related features) is included in Appendix C at the end of this thesis.

Most sites were tentatively dated to the Late Iron Age (LIA) using information derived from the presence of roulette-decorated ceramics, mainly knotted strip roulette (KPR; Soper 1985), although there were some examples of twisted string roulette (TGR) as well as other decorative techniques (*cf.* Appendix C). Several sites were located with Urewe pottery (Posnansky 1961b), typical of the Early Iron Age (EIA). However, such sites were uncommon – only five sites with Urewe were identified, with only a few sherds per site, which fits with previous survey data from the region (*cf.* Chapter 2).

Although the main thrust of this research was archaeometallurgical, the nature of the survey methodology meant that frequent conversations were had with local residents, every day of the survey (see also Shimada 1994; Juleff 1998). Sometimes, informants were encountered who had either witnessed smelting or had taken part in it themselves when they were younger, providing valuable information and memories regarding smelting, recorded informally on the survey sheets (*cf.* Appendix D). Thoughts and initial interpretations of these conversations were presented at the World of Iron conference (London 2009) and are currently being prepared for publication in the conference proceedings (Iles, forthcoming). Although the information from these informants was by and large in agreement with Childs' and Buchanan's ethnographic work, reinforcing several prevailing ideas such as the complex relationship between women of child-bearing age and smelting, the concerted efforts that were made to retain knowledge within clans, and so on – themes that in some form are common to several of the recent iron producing communities of this area of Africa (e.g. Célis and Nzikobanyanka 1976; Herbert 1993; Reid and MacLean 1995) – others raised significant differences, to be discussed in Chapter 7.

Some of the sites with only slag remains were substantial: the site of Birenge (KYS3, *cf.* Figure 4.7) contained an estimated four hundred slag blocks that had been collected into two separate piles within neighbouring compounds (Figures 4.8 and 4.9). Similarly dense scatters were not infrequent within the landscape: iron production was clearly undertaken on a very large scale at some point during Mwenge's past. Several of these sites were sampled for later study; unfortunately to cover these additional sites within the timescale of this research would not have been possible.

Figure 4.8 Birenge, survey site KYS 3, Slag Cluster 1 (looking north)

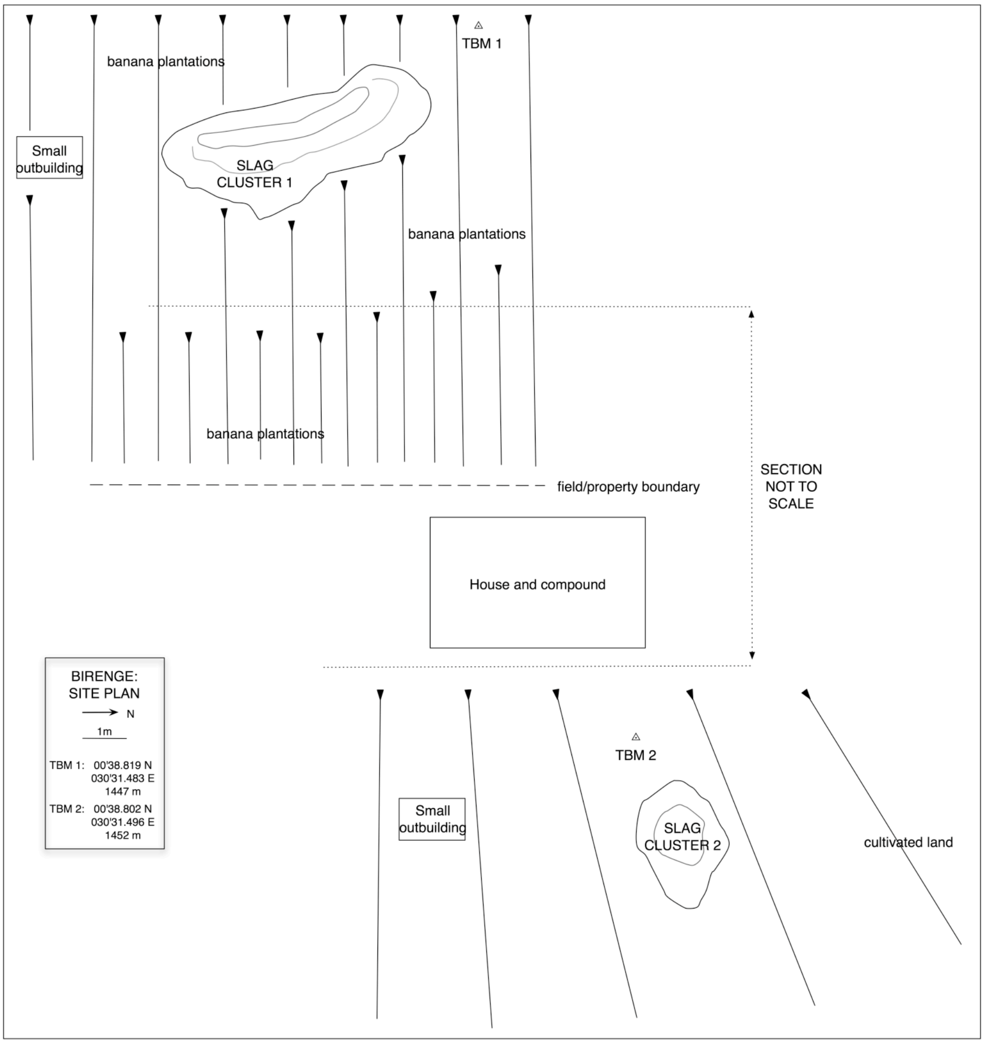


Figure 4.9 Site plan of Birenge, survey site KYS 3

There were factors that inevitably will have skewed some of the data collected (or not collected) during survey. There had been organised purchase of slag blocks *en masse* in recent years. In several cases, enterprising individuals were said to have paid local farmers for their unwanted slag blocks, which they removed from their original locations in large lorries for further sale, ultimately for use in building or road works. In one instance, inmates from a local prison had been sent into the local area to collect slag blocks as part of their community service, to be used in the construction of new prison buildings. In areas with industrialised commercial agriculture, tractors and other mechanised farming methods had noticeably broken up and dispersed slag blocks, unlike the impact made by hoe-based subsistence agriculture. It can reliably be assumed, therefore, that further large-scale sites with hundreds of slag blocks may have since disappeared from the archaeological record.

SITE SELECTION AND APPLIED EXCAVATION METHODOLOGY

Due to the large number of iron production sites located during survey, not all of them could be chosen for excavation. In light of this, six sites in the Mwenge area were selected for further investigation and excavation, based on their relative geographical locations and their archaeological potential (Figure 4.10). Sites with furnace remains that appeared to be relatively undisturbed, along with reasonably extensive slag scatters were selected. One site (Rukomero) was selected as two prominent furnace bases had been identified, offering a further resolution of smelting data at that site. Five of the sites (Rugombe, Kisamura, Mirongo, Rukomero and Kirongo) were located within a 100km^2 area in the southwest of the survey zone – the 'core' area where there was the greatest intensity of iron production sites – in order to assess the extent of variability in iron technologies within a limited geographical area. Further north, one site outside of this zone (Kyakaturi) was also excavated to extend the area under investigation, and to test variation on a broader scale.

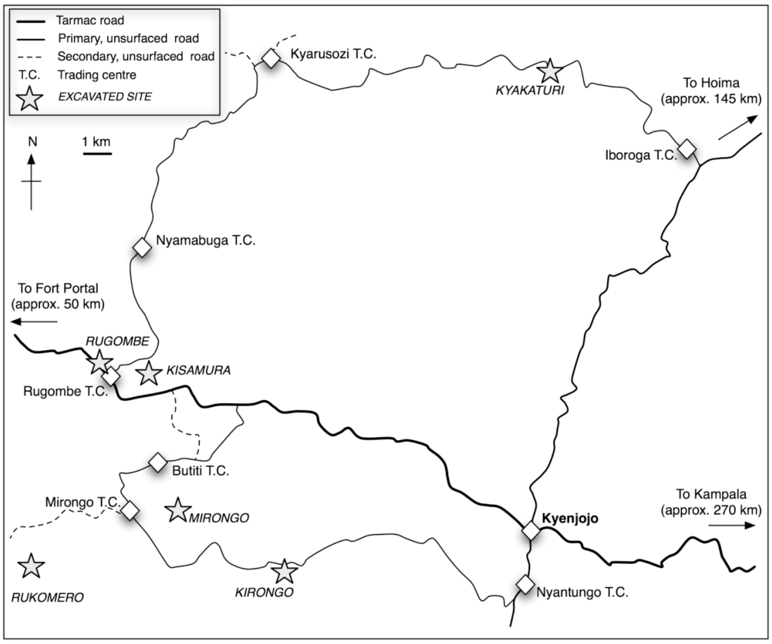
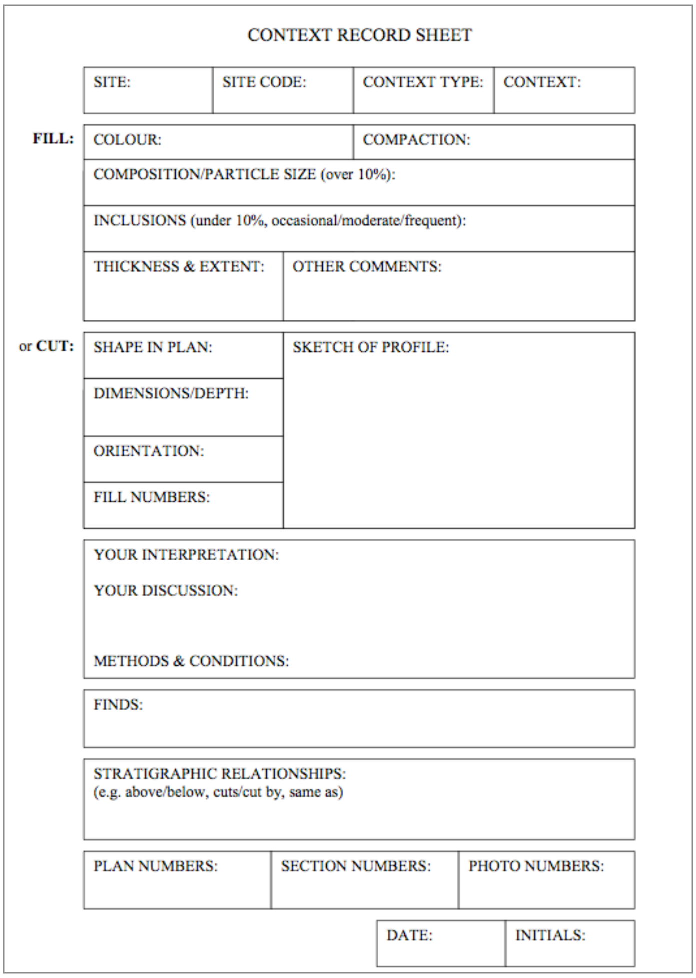


Figure 4.10 Sites excavated during the 2007 fieldwork in Mwenge

Although it may have been an interesting and significant line of investigation, my equipment and experience (or lack thereof) did not permit me to lead excavation at any of the mining sites that had been located. The pits that were encountered were very deep and narrow, and by their nature tended to be located in areas that were not easy to access; for reasons of safety, excavating these features was not a risk I was prepared to take with my team.

For the purposes of comparison, all of the sites selected for excavation (across the three survey zones, as well as across Mwenge) were characterised by a dominance of KPR wares, indicative of the Late Iron Age (i.e. post-c.800 AD). However, as the ceramic chronology in this region is so poorly defined, radiocarbon dating was also employed on charcoal samples recovered from all excavated furnaces with the aim of placing these sites within a more specific chronological framework.

The initial task on arriving at a site was to negotiate access and compensation (for any damage to crops or inconvenience caused) with the landowner and local administrative officers, followed by introducing ourselves and our work to interested residents in the local language(s) (communicated by my research assistant, Elijah Kisembo). An intensive survey of the immediate site would then be undertaken, in order to locate all visible archaeological features prior to excavation. The area would then be cleaned back, planned and photographed. All visible archaeological features were excavated, although these were rare, generally comprising only the original furnace remains that had been noted. A test pit (usually measuring two metres by one metre) was also excavated in an area of the site close to the furnace and/or slag remains that appeared to bear the thickest deposits. All features were half-sectioned and recorded prior to being fully excavated, and were excavated by context, with reference to the Museum of London archaeological site manual (MoLAS 1994; Figure 4.11). In test pits, thick deposits were excavated in 10cm spits, otherwise these too were excavated by context. All contexts were planned individually, and selected sections were drawn and photographed. Furnace bases were dug through in order to ensure there were no remains underneath. All excavated areas were backfilled. A site diary was kept at each site, and updated daily.


CONTEXT RECORD SHEET

SITE: | SITE CODE: | CONTEXT TYPE: | CONTEXT:

FILL: COLOUR: | COMPACTION:

COMPOSITION/PARTICLE SIZE (over 10%):

INCLUSIONS (under 10%, occasional/moderate/frequent):

THICKNESS & EXTENT: | OTHER COMMENTS:

or CUT: SHAPE IN PLAN: | SKETCH OF PROFILE:

DIMENSIONS/DEPTH:

ORIENTATION:

FILL NUMBERS:

YOUR INTERPRETATION:

YOUR DISCUSSION:

METHODS & CONDITIONS:

FINDS:

STRATIGRAPHIC RELATIONSHIPS:
(e.g. above/below, cuts/cut by, same as)

PLAN NUMBERS: | SECTION NUMBERS: | PHOTO NUMBERS:

DATE: | INITIALS:

Figure 4.11 Context recording sheet used during the 2007 excavations

In addition, primary sampling of slag blocks was done on-site, in order to reduce the weight of the samples taken back to Kampala, and hence to London. A sample of slag blocks was undertaken once all the slag blocks had been cleaned, described and fully recorded (*cf.* Figure 4.12). The intention from this sampling was to provide a representative sample of what appeared to be 'typical' slag blocks at each site, as well as sampling from any anomalous blocks. Priority was given to complete slag blocks, from which most data could be extracted. Selected slag blocks were drawn, photographed and weighed, and then half-sectioned using a sledgehammer; the resulting section was then drawn and photographed (Figures 4.13 and 4.14).

SLAG BLOCK RECORD SHEET

SITE:	SITE CODE:	CLUSTER:	SLAG NUMBER:

SHAPE IN PLAN (sketch):	SHAPE IN PROFILE (sketch):
COLOUR:	CORROSION:
PLANT IMPRESSIONS (frequency, position, species):	

DIMENSIONS:	WEIGHT:
DENSITY (comparative):	FLOW STRUCTURE:

ANNOTATED SKETCH OF HALF-SECTION:

SAMPLES TAKEN (mark locations on above sketch):

FURTHER COMMENTS (process suggestions, fractured edges, impressions of furnace wall etc):

PLAN NUMBERS:	SECTION NUMBERS:	PHOTO NUMBERS:

DATE:	INITIALS:

Figure 4.12 Slag block recording sheet used during the 2007 excavations

Figure 4.13 Using a sledgehammer to section a slag block

Figure 4.14 Sectioned slag block from Kisamura (Cluster 2, Slag 3)

Samples were taken from the top, middle and bottom of the block, representing the end, middle and beginning of that smelting episode (specimens are labelled T, M and B respectively in tables, or C if an additional sample was taken from a defined upper crown area). If the block appeared visually heterogeneous, further samples were taken from anomalous areas. This sampling approach followed that developed by Jane

Humphris in Buganda, with the intention of enabling a detailed reconstruction of singular smelting events to be inferred from the analyses (*cf.* Humphris *et al.* 2009).

All excavated remains were removed from site to be stored at the Uganda Museum in Kampala, where more detailed, non-destructive documentation was carried out on all samples. The dimensions, morphology, flow structure and mass of the slag samples were recorded – characteristics which are related to furnace design and operation. For the tuyère samples, the internal and external curvatures of the tuyère fragments were measured and calculated to give estimates of diameters, and the bulk samples were weighed. The ceramic fabrics were visually characterised, and any additional indications of the method of manufacture were noted. The angles of any vitrified drips of tuyère were also recorded, as they are relevant to understanding the position of the tuyères within the furnace body. Furnace wall and ore samples were weighed as bulk samples, and all samples were photographed. Samples of slag, tuyère and domestic pottery from secure contexts were selected, alongside furnace wall and potential ore samples, in order to be transported to UCL Institute of Archaeology for further analysis.

In London, a sub-set of typical and atypical samples, which were considered most representative of the full range of the study material, was then selected for specimen preparation in order to undertake the analytical procedures described below. Stratified sampling methods were employed at each stage to ensure that there was a balanced representation of every subgroup of the assemblage in the final sample set (Orton 2000: 30).

PART TWO: ANALYTICAL METHODOLOGY

Three analytical techniques were employed in the archaeometallurgical analysis of this material: optical microscopy, scanning electron microscopy with an energy dispersive spectrometer (SEM-EDS), and polarising energy dispersive x-ray fluorescence (PED-XRF) using compressed powder pellets. Used together, these complementary methodologies are able to provide bulk chemical compositions of materials under examination, as well as characterising phase composition. All of these analyses were undertaken at the UCL Institute of Archaeology Wolfson Archaeological Science Laboratories. Detailed notes were kept at each stage of the lab processes.

SAMPLE PREPARATION

For optical microscopy and SEM-EDS analysis, resin-mounted polished blocks were prepared following standard procedures. Specimens of approximately $1cm^3$ were cut from each selected tuyère and slag sample using an abrasive tile cutter, and these were then set in a two-part epoxy resin, with a ratio of resin to hardener of 1:5. The set specimens were ground and then polished using a diamond paste to a grade of 0.25μm. Following the optical microscopy, samples that were intended for SEM-EDS analysis were coated with a thin layer of carbon by evaporative coating in order to increase the conductivity of the specimen and prevent charge accumulation.

For the quantitative PED-XRF analysis, compressed powder pellets of the selected tuyère, slag, furnace wall and ore samples were prepared using standard sample preparation procedures. These procedures were directly comparable to those used to prepare the standards used to calibrate the PED-XRF machine, in order that statistically comparable data would be produced. Approximately 20g of representative material were removed from each of the slag and ore samples (15g of the ceramic samples) using a diamond-coated tile cutter blade. The minimum weight required to make a powder pellet is approximately 8g, but in this case 15-20g was taken in order to compensate somewhat for any localised heterogeneity within the material. Material was taken from tuyère and furnace lining fragments that showed no visible signs of vitrification, so as to provide a chemical composition of the ceramic with minimal contamination from the furnace charge. Any parts of the slag and ore samples that bore visible corrosion products were removed and discarded, and were not integrated into the bulk analysis so as not to skew the resultant data.

The resulting bulk materials were crushed using a steel percussion mortar and pestle, before being milled in a planetary ball mill to produce a powder with a grain size of less than 50μm. Agate pots and balls were used to mill ceramic materials; tungsten carbide balls in steel pots were used to mill slags and ores. The milled sample powders were dried overnight before being mixed with a wax binding agent at a ratio of 8g of sample to 0.9g of wax. These mixtures were then compressed in a hydraulic press at 15 tons for 2.5 minutes to produce the final pressed pellets.

Alternative sample preparation procedures, specifically fused beads, exist for ED-XRF procedures, which may improve the accuracy of results, especially for major elements. In the ED-XRF process, as the x-rays only penetrate a short distance into the sample, only a small portion of any prepared sample will ultimately be analysed. In the case of compressed pellets, only the first layer of grains will be excited by the x-rays, so it is important that this layer is as representative as possible. Using the fused bead methodology, the sample is melted with a flux at high temperature and subsequently cast, resulting in a homogeneous glass bead; the data produced from this prepared sample might be considered more representative than that of a compressed pellet, although this is not necessarily the case. Furthermore, the non-crystalline glass (in contrast to a powder) presents with fewer issues of matrix and mineralogical effects, such as fluorescence, diffraction or absorption that may slightly distort the results. As more diluted samples, glass beads also minimise the possibility of major peaks overwhelming the detector or absorbing other peaks. However, all preparation techniques have advantages and disadvantages. Cost and speed need to be assessed against the level of accuracy required, and the preparation of fused beads is certainly more costly and time consuming, and would require the acquisition of new equipment by the Institute of Archaeology. Compressed pellets of the type used here have repeatedly been shown to produce appropriate and sufficient results for similar investigations of iron production technologies (*cf.* Veldhuijzen 2005; Charlton 2007; Humphris 2010). The use of certified reference materials alongside every PED-XRF analytical run carried out for this research goes some way to ensuring that this methodology produces accurate and precise results. This will be discussed further in the following section.

PED-XRF

The principal quantitative technique was polarising ED-XRF analysis (PED-XRF). ED-XRF analysis operates on the principle that primary x-rays are used to irradiate and excite the atoms of a prepared sample. X-ray photons are emitted as a result of this excitation, the energies of which are specific to the atoms from which they originated. An energy dispersive spectrometer detects and measures the energy of the photons, and counts how many there are of each energy, thereby allowing for a characterisation of the chemical composition of the sample (Pollard and Heron 1996: 41-45). It is relatively simple and inexpensive compared to other techniques, and provides excellent minor and trace element analysis, and reasonable major element analysis of overall chemical compositions (Joosten 2004: 38).

In this case, *polarising* ED-XRF analysis was used to provide quantitative bulk chemical analyses of the selected samples of ore, furnace wall, slag and tuyère. Polarising ED-XRF reduces the background spectral 'noise' of the data as compared to traditional ED-XRF, meaning that detection limits are much lower, generally down to tens of parts per million. For this study, a Spectro Lab XPro 2000 instrument was used with five secondary targets, run with a Slag_Fun evaluation programme that is well suited to the analysis of iron-rich materials (Veldhuijzen 2003), calibrated for use with compressed pellets. Three measurements were taken from each sample, which were averaged to give a final result. The close correspondence between these measurements demonstrated the high level of precision of the instrument (*cf.* for example, Appendix F). However, oxygen cannot be detected by the PED-XRF, and as such, major and trace elements were converted to oxides by stoichiometry. In the case of iron, it is reported as the oxide of Fe^{2+}, as this is the most commonly occurring valence of iron seen in the slag samples studied microscopically, e.g. wüstite (FeO) or fayalite

(Fe_2SiO_4)[2]. The results were normalised to 100% to allow for easy comparison between samples, but the original measured totals are also reported, so that the reader can easily and independently assess the reliability of the data. All results are reported in full in the Appendices indicated in Chapters 5 and 6.

Several checks were carried out to ensure that this methodology was producing acceptable results. Firstly, three calibration standards of known (or agreed) chemical compositions (Reference Materials or RMs) were run alongside each type of sample (i.e. ceramic, or slag and ore) in every run in order to identify any instrumental errors, thereby allowing an assessment of the accuracy and reliability of the resultant data. These RMs were chosen to match as closely as possible the approximate bulk chemical compositions of the samples to be analysed. The RMs run with the slag and ore samples were BCS 301 Lincolnshire Iron Ore (Bureau of Analysed Samples (BAS) 2010), ECRM 681 Iron Ore (BAS 2010) and Swedish Slag (Kresten and Hjärthener-Holdar 2001; Paynter 2006). The RMs run with the ceramic samples were SARM 69 Ceramic (South African Reference Materials 2006), NIST 76a Burnt Refractory (National Institute of Standards and Technology 2005) and ECRM 776 Firebrick (BAS 2010).

The precision of the data was assessed by comparing the repeated runs of each RM and calculating the coefficients of variation (CVs). In order to assess the accuracy of the results, the data generated from each run was compared to the published compositions for each of the standards, and the absolute and relative errors were calculated. The results of these calculations are presented in Tables 4.1 to 4.6 and discussed below.

[2] In the analyses of the RMs, the iron oxide contents have been converted by stoichiometry to match that provided in the published compositions, to facilitate comparison.

BCS 301 *Lincolnshire iron ore*	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	MnO wt%	Fe_2O_3 wt%	Analytical total wt%
Reference values	**0.10**	**2.37**	**5.83**	**10.12**	**1.09**	**0.55**	**0.44**	**30.91**	**0.22**	**1.71**	**46.68**	**73.12**
Measurements:												
16/11/09	0.07	1.73	5.82	12.83	0.97	0.32	0.46	29.09	0.17	1.56	46.50	74.06
24/11/09	0.05	1.70	5.80	12.73	0.95	0.32	0.46	29.04	0.18	1.59	46.71	73.12
25/11/09	0.05	1.68	5.77	12.78	0.96	0.31	0.46	29.01	0.18	1.57	46.75	73.89
27/11/09	0.11	1.70	5.93	13.02	0.95	0.32	0.46	28.85	0.18	1.57	46.44	74.48
30/11/09	/	1.66	5.90	12.94	0.96	0.32	0.46	29.00	0.17	1.57	46.56	74.04
7/12/09	0.07	1.67	5.80	12.83	0.97	0.32	0.46	29.05	0.18	1.59	46.57	73.38
8/12/09	0.12	1.56	6.45	13.34	0.93	0.31	0.46	28.59	0.19	1.57	46.00	73.65
11/1/10	/	1.70	5.80	12.83	0.96	0.32	0.46	29.06	0.17	1.56	46.68	73.22
12/1/10	/	1.64	5.84	12.89	0.97	0.33	0.46	29.15	0.16	1.55	46.56	74.02
14/1/10	/	1.64	5.78	12.81	0.95	0.32	0.46	29.08	0.18	1.59	46.70	73.23
Precision:												
mean	**0.08**	**1.67**	**5.89**	**12.90**	**0.96**	**0.32**	**0.46**	**28.99**	**0.18**	**1.57**	**46.55**	**73.71**
std dev	**0.03**	**0.05**	**0.20**	**0.18**	**0.01**	**0.01**	**0.00**	**0.16**	**0.01**	**0.01**	**0.22**	
CV (%)	**40**	**3**	**3**	**1**	**1**	**2**	**0**	**1**	**5**	**1**	**0**	
Accuracy:												
δ absolute	**-0.02**	**-0.70**	**0.06**	**2.78**	**-0.14**	**-0.23**	**0.02**	**-1.92**	**-0.04**	**-0.14**	**-0.13**	
δ relative (%)	**-19**	**-30**	**1**	**27**	**-12**	**-42**	**5**	**-6**	**-19**	**-8**	**0**	

Table 4.1 Normalised PED-XRF results generated from BCS 301 in comparison to normalised published compositions (only reported oxides are shown here)

ECRM 681 *Iron ore*	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	Fe_2O_3 wt%	Analytical Total wt%
Reference values	**0.11**	**1.74**	**12.48**	**20.93**	**2.37**	**0.12**	**0.69**	**4.61**	**0.56**	**0.16**	**0.07**	**0.33**	**55.83**	**85.11**
Measurements:														
16/11/09	0.36	1.19	13.77	24.38	2.34	0.14	0.63	4.32	0.46	0.15	0.08	0.32	51.31	89.74
24/11/09	0.34	1.15	13.81	24.47	2.35	0.15	0.63	4.32	0.46	0.15	0.08	0.32	51.20	89.16
25/11/09	0.27	1.19	13.80	24.40	2.34	0.15	0.63	4.34	0.47	0.15	0.08	0.33	51.29	90.19
27/11/09	0.36	1.15	13.75	24.53	2.32	0.15	0.64	4.31	0.47	0.15	0.08	0.32	51.21	90.57
30/11/09	0.25	1.19	13.72	24.47	2.34	0.15	0.64	4.32	0.46	0.15	0.08	0.32	51.36	90.13
7/12/09	0.36	1.15	13.65	24.33	2.33	0.15	0.63	4.33	0.47	0.15	0.08	0.32	51.48	89.45
8/12/09	0.35	1.14	14.01	24.63	2.26	0.15	0.63	4.27	0.47	0.15	0.08	0.32	50.98	90.62
11/1/10	0.23	1.12	13.82	24.52	2.36	0.15	0.63	4.34	0.47	0.15	0.08	0.32	51.23	89.78
12/1/10	0.22	1.16	13.77	24.56	2.34	0.15	0.63	4.34	0.47	0.15	0.08	0.32	51.25	88.82
14/1/10	0.19	1.16	13.63	24.48	2.34	0.15	0.64	4.33	0.47	0.15	0.08	0.33	51.51	89.11
Precision:														
mean	**0.29**	**1.16**	**13.77**	**24.48**	**2.33**	**0.15**	**0.63**	**4.32**	**0.47**	**0.15**	**0.08**	**0.32**	**51.28**	**89.76**
std dev	**0.07**	**0.02**	**0.10**	**0.09**	**0.03**	**0.00**	**0.00**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.15**	
CV (%)	**23**	**2**	**1**	**0**	**1**	**3**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	
Accuracy:														
δ absolute	**0.19**	**-0.58**	**1.29**	**3.55**	**-0.04**	**0.03**	**-0.06**	**-0.28**	**-0.10**	**-0.01**	**0.01**	**-0.01**	**-4.55**	
δ relative (%)	**177**	**-33**	**10**	**17**	**-2**	**28**	**-9**	**-6**	**-17**	**-7**	**16**	**-2**	**-8**	

Table 4.2 Normalised PED-XRF results generated from ECRM 681 in comparison to normalised published compositions (only reported oxides are shown here)

Swedish slag	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	MnO wt%	FeO wt%	Analytical Total wt%
Reference values	**0.62**	**0.43**	**7.71**	**25.55**	**0.30**	**0.04**	**1.06**	**1.46**	**0.35**	**3.21**	**59.28**	**100.14**
Measurements:												
16/11/09	0.69	0.22	6.97	27.96	0.11	0.14	1.06	1.39	0.21	2.65	58.22	106.87
24/11/09	0.64	0.24	6.98	27.99	0.12	0.13	1.06	1.39	0.21	2.69	58.15	107.42
25/11/09	0.63	0.22	6.95	28.02	0.10	0.14	1.07	1.39	0.21	2.66	58.23	106.48
27/11/09	0.62	0.23	7.07	28.07	0.10	0.14	1.06	1.40	0.21	2.65	58.08	107.39
30/11/09	0.63	0.23	7.03	27.98	0.10	0.14	1.07	1.40	0.21	2.67	58.18	106.71
7/12/09	0.60	0.20	6.95	28.10	0.11	0.13	1.06	1.42	0.21	2.67	58.17	106.88
8/12/09	0.67	0.26	7.62	28.02	0.13	0.14	1.05	1.40	0.21	2.63	57.49	108.77
11/1/10	0.59	0.22	7.10	28.21	0.11	0.13	1.05	1.40	0.21	2.68	57.91	107.53
12/1/10	0.60	0.17	7.06	28.17	0.12	0.12	1.06	1.42	0.21	2.69	58.01	109.12
14/1/10	0.56	0.19	7.01	28.07	0.11	0.13	1.06	1.40	0.21	2.68	58.18	107.42
Precision:												
mean	**0.62**	**0.22**	**7.08**	**28.06**	**0.11**	**0.13**	**1.06**	**1.40**	**0.21**	**2.67**	**58.06**	**107.46**
std dev	**0.04**	**0.02**	**0.20**	**0.08**	**0.01**	**0.01**	**0.00**	**0.01**	**0.00**	**0.02**	**0.22**	
CV (%)	**6**	**11**	**3**	**0**	**9**	**6**	**0**	**1**	**1**	**1**	**0**	
Accuracy:												
δ absolute	**0.00**	**-0.21**	**-0.63**	**2.51**	**-0.19**	**0.09**	**0.00**	**-0.06**	**-0.14**	**-0.54**	**-1.21**	
δ relative (%)	**0**	**-49**	**-8**	**10**	**-63**	**236**	**0**	**-4**	**-39**	**-17**	**-2**	

Table 4.3 Normalised PED-XRF results generated from Swedish Slag in comparison to normalised published compositions (only reported oxides are shown here)

In terms of precision, the coefficients of variation (CVs) of the slag-like RMs show that the results generated over the two months of slag analysis were very precise and highly replicable. Generally the CVs were seen to be under 10%, with only three exceptions in the lighter compounds (soda and magnesia); most CVs ranged between 0 and 3%.

The accuracy of the results was more variable regarding the slag-like RMs, but still of acceptable quality in general (Table 4.4). Compared to the reference values, the calculated accuracy errors of the major compounds of alumina, potash, lime and iron oxide were all less than 10%, and in many cases much lower. Titania, present in the standards in concentrations of less than 0.6wt%, was consistently underestimated, by an average of 25%. As was to be expected, sensitivity to the lighter compounds of soda and magnesia, as well as sulphur (present at only minor levels), was reduced, and readings for these are particularly inaccurate.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_{ox}
BCS 301	-19	-30	1	27	-12	-42	5	-6	-19	/	/	-8	0
ECRM 681	177	-33	10	17	-2	28	-9	-6	-17	-7	16	-2	-8
Swedish slag	0	-49	-8	10	-63	236	0	-4	-39	/	/	-17	-2

Table 4.4 ∂ relative values as shown in Tables 4.1 to 4.3

Silica, however, was problematic, with consistent overestimations of quite significant amounts, ranging between 10 and 27%, effecting changes in estimated composition ranging up to around 4wt%. The less silica there was, the larger the overestimation[3]. In order to compensate for this, silica levels in the slag and ore samples were adjusted on a sliding scale. A graph was drawn (and extrapolated) from the data generated by the RM analyses to provide a guide by which to judge to what degree the sample data needed to be recalculated (Figure 4.15). For example, a slag sample showing a silica level of 10wt% would have been overestimated by approximately 27%, and would therefore need to be adjusted by a factor of 0.73 (i.e. (100-27) ÷ 100) to give a new, and hopefully more accurate silica content of 7.3wt%. Tables presenting the analytical results later in the text will show both original and adjusted values.

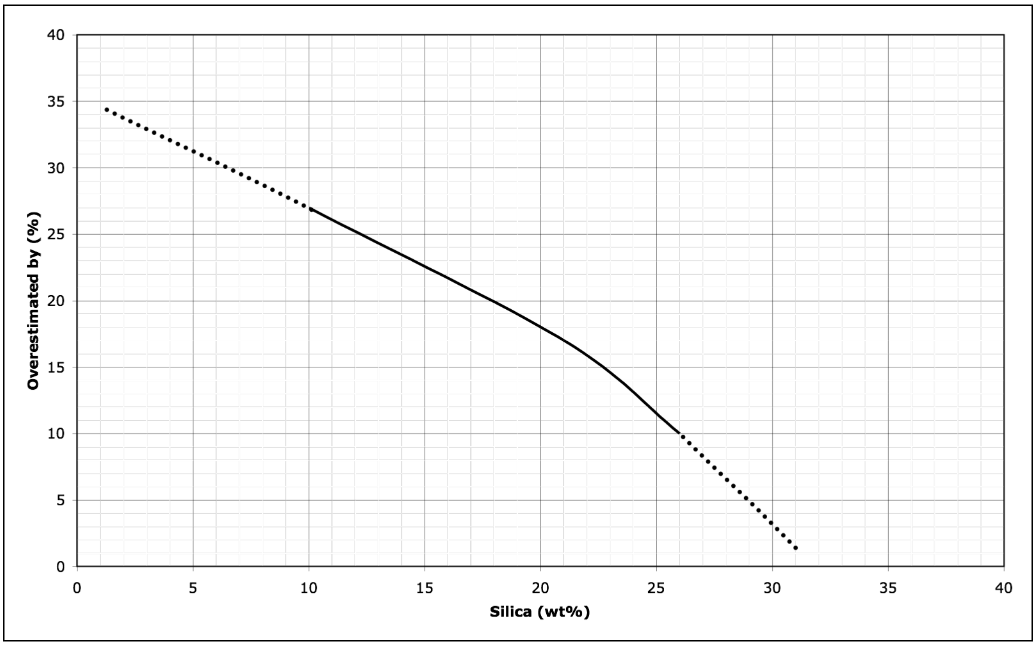


Figure 4.15 Silica compensation graph

Two other compounds followed a pattern of consistent and relative underestimation. Where phosphate was present in quantities of close to 1wt%, accuracy was moderate (with an average underestimation of 12%), but this improved to an underestimation of only 2% when phosphate levels rose above 2wt% as they were in ECRM 681. At levels of less than 0.5wt%, accuracy was seen to be poor. Manganese oxide was also

[3] At the levels of silica present in the ceramic samples, no adjustment was seen to be necessary (see ceramic RM measurements).

consistently underestimated, but the higher the manganese oxide content, the higher the underestimation appeared to be. With a content of 3wt%, the value was underestimated by a factor of 17%. This would have consequences for the interpretation of the data presented in Chapters 5 and 6, where manganese oxide levels were often found to be elevated above 3wt%.

Having confidence in the precision of the PED-XRF machine, a further question was asked of it. A sample of sand (usually used to clean the mill in between sample runs) milled in the agate milling equipment was compared to one milled in the steel pots and tungsten carbide balls (a cemented carbide, cobalt matrix composite), in order to investigate whether appreciable contamination was entering the slag and ore samples at this stage of sample preparation (Table 4.5). It appeared that some compositional differences did arise in the sand samples milled in the different equipment[4]. Although sands can be variable, some of these increases (in the steel/tungsten carbide equipment) were significant, and seem analogous to contributions from a cemented tungsten carbide: iron, cobalt and tungsten oxides showed appreciable increases, as did chromia and silica[5]. It will thus be assumed that low levels of these compounds are entering the compressed pellet samples of slag and ore during sample preparation; however, the fact that the compound showing the largest percentage increase in this instance – tungsten oxide – remained undetectable in all sample analyses, implies that the actual impact on sample results is negligible.

	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	K_2O wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	Fe_2O_3 wt%	Co_3O_4 ppm	CuO ppm	ZnO ppm	ZrO_2 ppm	Ba ppm	WO_3 ppm	PbO ppm
Agate pot sand	0.83	0.13	2.58	83.27	0.00	1.01	0.05	0.00	0.00	0.00	0.29	0	5	8	57	192	7	12
	0.80	0.12	2.53	82.62	0.00	1.01	0.06	0.00	0.00	0.00	0.29	8	5	7	63	200	6	10
	0.82	0.12	2.61	83.42	0.00	1.00	0.06	0.00	0.00	0.00	0.30	5	5	8	59	201	4	10
Average	***0.82***	***0.12***	***2.58***	***83.10***	***0.00***	***1.01***	***0.06***	***0.00***	***0.00***	***0.00***	***0.29***	***4***	***5***	***8***	***60***	***197***	***5***	***11***
Steel pot sand	0.00	0.00	2.51	87.20	0.01	1.01	0.06	0.00	0.05	0.00	0.55	70	7	13	79	198	1870	6
	1.09	0.13	2.62	87.74	0.00	1.03	0.06	0.00	0.05	0.00	0.56	67	5	12	75	200	1884	7
	1.00	0.12	2.63	87.55	0.00	1.04	0.06	0.00	0.05	0.00	0.56	71	9	16	76	198	1905	7
Average	***0.70***	***0.08***	***2.59***	***87.50***	***0.00***	***1.03***	***0.06***	***0.00***	***0.05***	***0.00***	***0.56***	***69***	***7***	***14***	***77***	***198***	***1886***	***7***

Table 4.5 PED-XRF data of two sands samples: one milled in the agate equipment, the other in the steel and tungsten carbide equipment. The data is not normalised

[4] These samples were run with an industrial standard TurboQuant (TQ-0261a) algorithm (Schramm and Heckel 1998).

[5] Although it is feasible that the different grain sizes achieved using each of the milling processes impacted slightly upon the measured compositions, particularly regarding silica.

Before analysis of the ceramic material, it was considered prudent to run a method check to assess whether the use of TurboQuant or Slag_Fun was the most appropriate evaluation programme for the ceramic samples of this study, as although TurboQuant was developed for the analysis of silica-rich material, this research was going to involve a reasonably high volume of comparison between PED-XRF data of slag and technical ceramic samples. If Slag_Fun produced as accurate results for technical ceramics, these datasets would be more comparable. Furthermore, TurboQuant was not programmed to measure neodymium – an element that was later found to be of relevance. In light of this, ceramic RMs were run using both TurboQuant and Slag_Fun to ascertain which gave the more accurate results. Again, since the precision of the PED-XRF had already been verified (at least regarding slag RMs), any differences in accuracy of measuring the composition of the standards would be due to the evaluation programme rather than a reading error. The results are presented below in Table 4.6. Overall, the results were fairly similar between the two evaluation programmes; accuracy in silica and alumina – compounds that will be frequently discussed in depth – was slightly improved with Slag_Fun. As such, Slag_Fun was chosen in order to ensure that comparison between the two sets of data was as meaningful as possible.

TurboQuant vs Slag_Fun **December 2009**	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	Fe_2O_3 wt%	NiO ppm	CuO ppm	ZnO ppm	SrO ppm	ZrO_2 ppm	BaO ppm
ECRM 776	**0.49**	**0.48**	**29.42**	**63.05**	**0.06**	**2.93**	**0.31**	**1.63**	**/**	**0.02**	**/**	**1.44**	**/**	**/**	**/**	**/**	**502**	**1206**
TurboQuant results:																		
mean	0.50	0.33	26.42	66.46	0.06	2.73	0.32	1.31	0.03	0.02	0.01	1.51					401	1853
δ absolute	0.01	-0.16	-3.00	3.41	-0.01	-0.21	0.01	-0.32		0.00		0.07					-102	648
δ relative (%)	**2**	**-33**	**-10**	**5**	**-9**	**-7**	**4**	**-20**		**19**		**5**					**-20**	**54**
Slag_Fun results:																		
mean	0.52	0.46	27.12	65.44	0.00	2.88	0.31	1.47	0.02	0.02	0.00	1.44					600	1544
δ absolute	0.03	-0.02	-2.29	2.39	-0.06	-0.06	0.00	-0.16		0.00		0.00					98	339
δ relative (%)	**6**	**-4**	**-8**	**4**	**-100**	**-2**	**-2**	**-10**		**8**		**0**					**20**	**28**
SARM 69	**0.82**	**1.92**	**14.92**	**68.98**	**0.29**	**2.03**	**2.45**	**0.80**	**0.03**	**0.03**	**0.13**	**7.44**	**70**	**60**	**88**	**133**	**379**	**599**
TurboQuant results:																		
mean	0.24	1.15	14.64	71.16	0.27	1.95	2.32	0.63	0.03	0.03	0.14	7.26	55	61	82	134	369	798
δ absolute	-0.58	-0.76	-0.28	2.18	-0.02	-0.08	-0.14	-0.18	0.00	0.00	0.01	-0.18	-15	1	-5	1	-10	199
δ relative (%)	**-71**	**-40**	**-2**	**3**	**-9**	**-4**	**-6**	**-22**	**-2**	**-6**	**5**	**-2**	**-21**	**2**	**-6**	**1**	**-3**	**33**
Slag_Fun results:																		
mean	0.28	1.37	15.53	70.10	0.20	2.08	2.35	0.66	0.00	0.03	0.12	7.02	56	61	70	132	630	759
δ absolute	-0.54	-0.55	0.62	1.12	-0.09	0.05	-0.10	-0.14	-0.03	-0.01	-0.01	-0.42	-14	1	-18	-1	251	160
δ relative (%)	**-66**	**-29**	**4**	**2**	**-32**	**3**	**-4**	**-18**	**-89**	**-16**	**-9**	**-6**	**-20**	**2**	**-21**	**-1**	**66**	**27**
NIST 76a	**0.49**	**0.52**	**38.72**	**54.93**	**0.12**	**1.33**	**0.22**	**2.03**	**/**	**/**	**/**	**1.60**	**/**	**/**	**/**	**400**	**/**	**/**
TurboQuant results:																		
mean	0.45	0.46	35.38	58.37	0.09	1.31	0.22	1.68	0.05	0.05	0.01	1.72				409		
δ absolute	-0.04	-0.06	-3.34	3.45	-0.03	-0.02	0.00	-0.35				0.12				9		
δ relative (%)	**-8**	**-12**	**-9**	**6**	**-26**	**-2**	**-1**	**-17**				**7**				**2**		
Slag_Fun results:																		
mean	0.34	0.59	35.92	57.60	0.04	1.36	0.21	1.93	0.03	0.04	0.00	1.64				406		
δ absolute	-0.15	0.07	-2.80	2.68	-0.08	0.02	-0.01	-0.10				0.04				6		
δ relative (%)	**-30**	**13**	**-7**	**5**	**-68**	**2**	**-6**	**-5**				**2**				**2**		

Table 4.6 Averaged PED-XRF data of ceramic RMs run using different evaluation programs: Slag_Fun and TurboQuant. Data has been normalised to 100%

The precision of the Slag_Fun method with the ceramic RMs was also good, with most compounds showing variation of between 0 and 4%, and almost all showing less than 15% variation. Again, soda was an exception, showing variation ranging between 18 and 50% (Tables 4.7 to 4.9).

SARM 69 *Ceramic*	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	Fe_2O_3 wt%	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	Rb_2O ppm	SrO ppm	ZrO_2 ppm	BaO ppm	CeO_2 ppm	Analytical total (wt%)
Certified values	**0.82**	**1.92**	**14.92**	**68.98**	**0.29**	**2.03**	**2.45**	**0.80**	**0.03**	**0.03**	**0.13**	**7.44**	**40**	**70**	**60**	**88**	**75**	**133**	**379**	**599**	**85**	**96.55**
Measurements:																						
8/12/09	0.28	1.37	15.53	70.08	0.20	2.08	2.35	0.66	0.00	0.03	0.12	7.02	144	56	61	70	78	132	630	758	148	97.25
22/1/10	0.27	1.35	15.20	70.29	0.20	2.08	2.38	0.66	0.00	0.03	0.12	7.15	142	56	61	70	79	134	620	755	205	97.18
22/1/10	0.29	1.38	15.14	70.31	0.20	2.09	2.37	0.67	0.00	0.03	0.12	7.11	131	59	60	70	78	133	631	763	170	97.72
25/1/10	0.17	1.36	15.26	70.40	0.20	2.09	2.37	0.66	0.00	0.03	0.12	7.07	138	57	59	68	78	133	602	743	152	97.53
Precision:																						
mean	**0.25**	**1.36**	**15.28**	**70.27**	**0.20**	**2.08**	**2.37**	**0.66**	**0.00**	**0.03**	**0.12**	**7.09**	**139**	**57**	**60**	**69**	**78**	**133**	**621**	**755**	**169**	**97.42**
std dev	**0.06**	**0.02**	**0.17**	**0.14**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.05**	**6**	**1**	**1**	**1**	**0**	**1**	**13**	**8**	**26**	
CV (%)	**22**	**1**	**1**	**0**	**1**	**0**	**0**	**1**	**12**	**1**	**0**	**1**	**4**	**2**	**2**	**1**	**0**	**1**	**2**	**1**	**15**	
Accuracy:																						
δ absolute	**-0.57**	**-0.55**	**0.37**	**1.29**	**-0.09**	**0.05**	**-0.09**	**-0.14**	**-0.03**	**-0.01**	**-0.01**	**0**	**99**	**-13**	**0**	**-19**	**3**	**0**	**242**	**156**	**83**	
δ relative (%)	**-69**	**-29**	**2**	**2**	**-31**	**3**	**-4**	**-18**	**-86**	**-16**	**-10**	**-5**	**252**	**-19**	**0**	**-21**	**5**	**0**	**64**	**26**	**98**	

Table 4.7 Normalised PED-XRF results generated from SARM 69 using Slag_Fun in comparison to normalised published composition (only reported oxides are shown here). Measurements are the average of three analyses

NIST 76a *Burnt refractory*	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	K_2O wt%	CaO wt%	TiO_2 wt%	Fe_2O_3 wt%	SrO ppm	Analytical total (wt%)
Reference values	**0.50**	**0.53**	**39.68**	**56.28**	**0.12**	**1.36**	**0.23**	**2.08**	**1.64**	**410**	**97.54**
Measurements:											
8/12/09	0.34	0.59	35.90	57.56	0.04	1.35	0.21	1.93	1.63	406	89.91
22/1/10	0.24	0.53	35.63	58.00	0.04	1.36	0.20	1.94	1.68	408.6	89.98
22/1/10	0.24	0.55	35.81	57.82	0.04	1.36	0.20	1.93	1.66	409.4	90.27
25/1/10	0.25	0.56	35.68	57.84	0.04	1.36	0.20	1.94	1.66	408.6	90.92
Precision:											
mean	**0.27**	**0.56**	**35.75**	**57.81**	**0.04**	**1.36**	**0.20**	**1.93**	**1.66**	**408**	**90.27**
std dev	**0.05**	**0.02**	**0.12**	**0.18**	**0.00**	**0.00**	**0.00**	**0.01**	**0.02**	**1**	
CV (%)	**18**	**4**	**0**	**0**	**4**	**0**	**1**	**0**	**1**	**0**	
Accuracy:											
δ absolute	**-0.23**	**0.02**	**-3.92**	**1.52**	**-0.08**	**-0.01**	**-0.02**	**-0.15**	**0.02**	**-2**	
δ relative (%)	**-46**	**4**	**-10**	**3**	**-67**	**0**	**-9**	**-7**	**1**	**0**	

Table 4.8 Normalised PED-XRF results generated from NIST 76a using Slag_Fun in comparison to normalised published composition (only reported oxides are shown here). Measurements are the average of three analyses

ECRM 776 *Firebrick*	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	K_2O wt%	CaO wt%	TiO_2 wt%	Cr_2O_3 wt%	Fe_2O_3 wt%	ZrO_2 ppm	BaO ppm	Analytical total (wt%)
Reference values	**0.49**	**0.48**	**29.41**	**63.04**	**0.06**	**2.93**	**0.31**	**1.63**	**0.02**	**1.44**	**502**	**1205**	**99.56**
Measurements:													
8/12/09	0.52	0.46	27.10	65.40	/	2.87	0.31	1.47	0.02	1.44	600	1544	94.83
22/1/10	0.28	0.35	27.06	65.78	/	2.87	0.30	1.45	0.02	1.46	607	1533	95.08
22/1/10	0.17	0.35	27.09	65.86	/	2.89	0.30	1.46	0.02	1.45	612	1545	95.29
25/1/10	0.55	0.43	26.94	65.54	/	2.89	0.30	1.46	0.02	1.45	615	1556	95.07
Precision:													
mean	**0.38**	**0.40**	**27.05**	**65.64**	**/**	**2.88**	**0.30**	**1.46**	**0.02**	**1.45**	**609**	**1544**	**95.07**
std dev	**0.19**	**0.06**	**0.07**	**0.21**		**0.01**	**0.00**	**0.00**	**0.00**	**0.01**	**7**	**9**	
CV (%)	**49**	**14**	**0**	**0**		**0**	**1**	**0**	**1**	**1**	**1**	**1**	
Accuracy:													
δ absolute	**-0.11**	**-0.08**	**-2.36**	**2.61**		**-0.05**	**-0.01**	**-0.17**	**0.00**	**0.01**	**106**	**339**	
δ relative (%)	**-23**	**-17**	**-8**	**4**		**-2**	**-3**	**-10**	**7**	**1**	**21**	**28**	

Table 4.9 Normalised PED-XRF results generated from ECRM 776 using Slag_Fun in comparison to normalised published composition (only reported oxides are shown here). Measurements are the average of three analyses

The accuracy of the results was good for the major components of the ceramics – alumina and silica, as well as the minor compounds of potash, lime and iron oxide (Table 4.10). Titania was again consistently underestimated, by approximately 12%, with phosphate consistently underestimated significantly more. Other minor and trace compounds were more variable, presumably because they were present in lower concentrations. However, many of these are measured against tentative indicative values in the RMs rather than certified ones (for example, soda, phosphate and vanadium, zirconium and cerium oxides), which makes the lower accuracy of these values less troubling.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Rb_2O	SrO	ZrO_2	BaO	CeO_2
SARM 69	**-69**	**-29**	**2**	**2**	**-31**	**3**	**-4**	**-18**	**-86**	**-16**	**-10**	**-5**	**252**	**-19**	**0**	**-21**	**5**	**0**	**64**	**26**	**98**
NIST 76a	**-46**	**4**	**-10**	**3**	**-67**	**0**	**-9**	**-7**				**1**						**0**			
ECRM 776	**-23**	**-17**	**-8**	**4**		**-2**	**-3**	**-10**		**7**		**1**							**21**	**28**	

Table 4.10 ∂ relative values as shown in Tables 4.7 to 4.9

OPTICAL MICROSCOPY

Reflected light microscopy was chosen as a further analytical method in order to examine the mineralogical compositions and internal microstructures of the slag and tuyère samples. This approach provided an initial indication of the fabrics of the tuyère samples, and of the different phases and crystal sizes present in the slag samples, and also allowed for an assessment of the homogeneity of the samples, as well as establishing the presence and nature of weathering products and inclusions such as charcoal, quartz grains or metallic prills. Descriptions of the crystal structures and their sizes and arrangements can provide significant insights into the types of processes that created specific slag types (Bachmann 1982; Joosten 2004: 35); visible markers of ceramic vitrification and examination of inclusions can indicate how tuyère samples were made and used. Plane polarised light (PPL) microscopy was complemented by cross-polarised light (XPL) microscopy where appropriate. Digital images were produced of both typical and distinctive features of the specimens, and preliminary examination under an optical microscope was used to identify areas of interest in preparation for further SEM-EDS study.

SEM-EDS

Scanning electron microscopy was carried out on selected samples of tuyère, slag and ore, allowing microstructural examination and image production of these samples at a higher magnification than optical microscopy (Jones 2001: 24). More importantly, SEM-EDS analysis was used to determine elemental compositions of specific areas of the samples, which produced a more detailed understanding of the internal chemical make-up of the samples and the distribution of elements across different phases (Pleiner 2000: 252). SEM-EDS analysis operates on the principle that an electron beam directed at a prepared sample under a vacuum will excite the surface of the sample and cause electrons and x-ray photons to be emitted from it. Detection of the emitted electrons is used to generate optical images of the sample surface. Secondary electrons (SE) are low energy, and so only those emitted from atoms nearest to the surface will reach the detector. As such, raised areas of the sample are more likely to produce secondary electrons that can be detected, and therefore a secondary electron image will generally reflect the topography of the sample (and thus is of limited use here given that the sample material was prepared as polished blocks). Backscattered electrons (BSE), of higher energy, are a result of the interaction of the incident electron beam with the nucleus of the atoms, and their intensity is related to the average atomic number of the different phases of the exposed sample area, thereby giving a visual representation of the chemical make-up of the sample. Detection of the emitted x-ray photons, as measured and counted by the EDS, provides a chemical analysis of selected areas of the sample, as each element will produce photons of a characteristic energy (Pollard and Heron 1996: 51-52).

This methodology is particularly useful when dealing with heterogeneous materials such as slag, as specific areas of interest within the sample can be pinpointed and analysed for elemental composition. As well as being used to confirm the chemical composition of crystal structures identified through optical microscopy, this technique was also used to characterise those that were previously unidentifiable.

Regarding the ceramic samples, SEM-EDS analysis was undertaken not only to identify inclusions that were not recognised through optical microscopy, but also to generate a more accurate chemical analysis of the ceramic matrices of consolidated ceramic samples. This is important as a bulk chemical analysis will include the compositions of any inclusions or temper (such as quartz or slag); a targeted chemical analysis of the matrix alone will facilitate an understanding of the properties of the clay itself (Freestone and Tite 1986: 39). This was achieved by calculating the mean average of two or three small area analyses of portions of the matrix free from large inclusions, taken at 1000x magnification (i.e. an approximate area size of 20μm by 50μm).

For this study, a Hitachi S-3400N scanning electron microscope with an attached Oxford Instruments EDS was used, at an accelerating voltage of 20kV and at a working distance of 10mm. INCA analysis software was used to translate the measured analytical spectra into compositional data of weight percentages, presented as oxides calculated by stoichiometry. Calibration of the EDS was undertaken at approximately 20-30 minute intervals throughout the analysis using a cobalt standard, to ensure continued operation at a sufficient level of quantitative reliability. Analytical totals were routinely checked, but results were normalised to 100% to account for internal sample porosity and small variations in beam intensity, and also to facilitate comparisons within the data set and with other published data.

Once again, to check the reliability of the data generated using this approach, standards with published compositions were analysed under the same conditions as the samples. Three basalt RMs, in the form of homogeneous glass, were used: BHVO-2 (Basalt, Hawaiian Volcanic Observatory, U.S. Geological Survey Geochemical Reference Materials and Certificates (USGS) 1998), BIR-1 (Icelandic Basalt, USGS 1998) and BCR-2 (Basalt, Columbia River, USGS 1998). For each RM, three small area readings were taken, measuring approximately 20μm by 20μm. The results were normalised and are presented below in Tables 4.11 to 4.13. As can be seen from the ∂ relative figures, the levels of accuracy are very high, not ranging above 10% in the major compounds. Accuracy regarding some of the trace compounds – zirconia, and vanadium and zinc oxides, with values at or below ordinary detection limits of an SEM-EDS – was significantly lower.

BCR-2	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Fe_2O_3 wt%	ZnO wt%	ZrO2 wt%	SrO wt%
Certified values	**3.2**	**3.6**	**13.5**	**54.1**	**0.4**	**1.8**	**7.1**	**2.3**	**0.1**	**13.8**			
Measurements:													
Area 1	2.8	3.0	12.4	56.7	0.4	2.0	7.6	1.9	0.1	13.8	0.8	/	/
Area 2	3.1	3.4	11.7	56.8	/	1.6	7.8	2.1	0.3	13.6	/	0.9	/
Area 3	3.3	3.6	12.9	56.2	0.6	1.8	7.0	2.3	/	13.5	/	/	0.1
Accuracy:													
mean	**3.1**	**3.3**	**12.3**	**56.6**	**0.3**	**1.8**	**7.5**	**2.1**	**0.1**	**13.6**			
∂ absolute	**-0.1**	**-0.3**	**-1.2**	**2.5**	**0.0**	**0.0**	**0.4**	**-0.2**	**0.1**	**-0.2**			
∂ relative (%)	**-3**	**-7**	**-9**	**5**	**-5**	**0**	**5**	**-7**	**75**	**-1**			

Table 4.11 Normalised SEM-EDS results generated from BCR-2 in comparison to the normalised published compositions

BIR-1	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	CaO wt%	TiO_2 wt%	MnO wt%	Fe_2O_3 wt%	V_2O_5 wt%
Certified values	**1.8**	**9.7**	**15.5**	**48.0**	**13.3**	**1.0**	**0.2**	**11.3**	**0.1**
Measurements:									
Area 1	1.6	9.4	14.7	50.2	12.8	1.1	0.3	11.1	/
Area 2	1.6	9.2	14.9	50.0	12.6	1.0	0.3	11.6	/
Area 3	2.0	9.6	14.3	49.5	13.4	1.0	/	11.2	0.1
Accuracy:									
mean	**1.7**	**9.4**	**14.6**	**49.9**	**13.0**	**1.0**	**0.2**	**11.3**	**0.0**
∂ absolute	**-0.1**	**-0.3**	**-0.9**	**1.9**	**-0.3**	**0.1**	**0.0**	**0.0**	**0.0**
∂ relative (%)	**-6**	**-3**	**-6**	**4**	**-3**	**8**	**9**	**0**	**-46**

Table 4.12 Normalised SEM-EDS results generated from BIR-1 in comparison to the normalised published compositions

BHVO-2	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Fe_2O_3 wt%
Certified values	**2.2**	**7.2**	**13.5**	**49.9**	**0.3**	**0.5**	**11.4**	**2.7**	**0.1**	**12.3**
Measurements:										
Area 1	2.2	7.1	12.9	51.8	0.2	0.5	11.4	2.8	0.2	12.2
Area 2	2.2	7.1	12.9	51.6	0.4	0.5	11.4	2.8	0.2	12.1
Area 3	2.1	7.3	12.7	52.4	0.2	0.5	11.2	3.0	0.0	12.0
Accuracy:										
mean	**2.1**	**7.2**	**12.8**	**51.9**	**0.3**	**0.5**	**11.3**	**2.9**	**0.1**	**12.1**
∂ absolute	**-0.1**	**-0.1**	**-0.7**	**2.0**	**0.0**	**0.0**	**-0.1**	**0.1**	**0.1**	**-0.2**
∂ relative (%)	**-3**	**-1**	**-5**	**4**	**-6**	**-3**	**-1**	**5**	**153**	**-2**

Table 4.13 Normalised SEM-EDS results generated from BHVO-2 in comparison to the normalised published compositions

DATING TECHNIQUES

As previously described, a detailed ceramic sequence is as yet undeveloped for this region. As such, during survey the sites were bracketed into large chronological/ceramic groups, based on the dominant type of decorated sherds per assemblage: EIA (i.e. pre-800 AD)/Urewe; LIA (i.e. post-800 AD)/Twisted-string Roulette; LIA/Knotted-strip Roulette (Posnansky 1961a, 1961b; Soper 1985; Desmedt 1991). However, funding was secured from the Oxford Radiocarbon Accelerator Dating Service to generate AMS dates for charcoal samples obtained from sealed contexts from within the excavated furnaces, in order to provide a tighter understanding of the chronological relationship of the sites. The dates generated will be presented in the following chapters on a site-by-site basis.

CHAPTER 5

TECHNOLOGICAL RECONSTRUCTIONS
MWENGE, PROTO-KINGDOM PERIOD

Three of the central Mwenge sites were radiocarbon dated to the fourteenth and fifteenth centuries AD. Descriptions of these sites, which fall within the years immediately preceding the formation of the Nyoro kingdom, will be addressed first in this chapter – in chronological order – accompanied by the analytical results relating to these sites. Later sites will be discussed in Chapter 6. The geographical locations of these earlier sites are indicated on the map below (Figure 5.1).

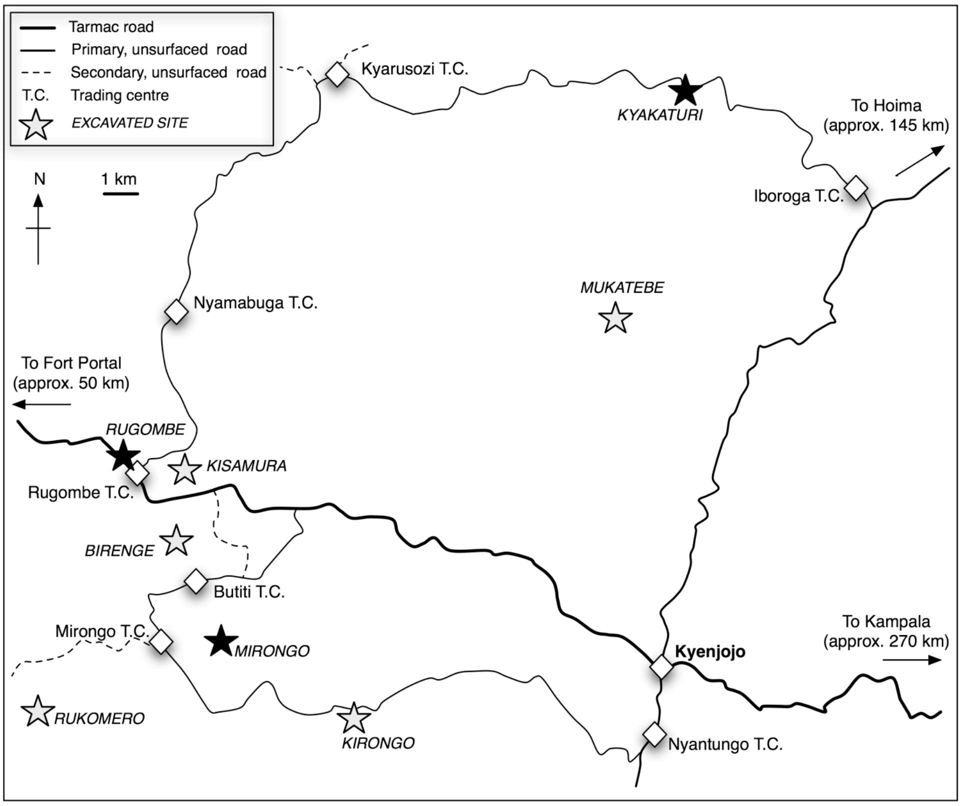


Figure 5.1 Map locating all excavated Mwenge sites in relation to major towns and roads. Sites discussed in this and the following chapter are marked with stars; those to be discussed in this chapter are marked with filled stars

PART ONE: KYAKATURI (KTR)

c. 14th century (1290-1398 cal. AD)

SITE DESCRIPTION

The small hamlet of Kyakaturi lies in the shadow of a ridge of forested hills to the far north of the central survey zone, approximately 7km due northwest of the junction town of Katooke, on the main Kyenjojo-Hoima road. A number of iron production and iron mining locations were identified in the vicinity of this village. One was selected for excavation and analysis as an outlying site, set apart from the main cluster of iron smelting sites that were located close to Butiti. The slag blocks from this area had an unusual greenish tinge of colour to them – a feature that hadn't been noted in other slag blocks from the Mwenge region. As such, in addition to the main research questions of this archaeometallurgical exploration, determining the cause of this distinctive colouring was a further reason for investigating Kyakaturi's smelting past.

The site that was chosen for excavation (KYS59) consisted primarily of a dense scatter of iron production remains – slag and tuyère fragments – that were eroding from a slightly sloping, southwest facing compound floor. The high density of slag in the ground meant that much of the surrounding land had been left fallow, the effort required to clear the land of the obstructive slag being deemed too intensive to be worth pursuing cultivation there. The faint remains of a furnace base were visible eroding out of an adjacent pathway, and it was the presence of these furnace remains that led to this site being chosen for excavation over the two further slag scatter sites that had been located nearby: KYS116 and KYS117. These both comprised further piles of slag blocks, which had been left to overgrow with thick vegetation, as once again cultivation was necessarily limited in these areas.

The Kagorra hills, which run behind the north-northeast line of the main road through the village (with its accompanying row of houses and compounds), are pockmarked with mining pits. Much of the hillside is currently commercially planted with Caribbean Pine (*Pinus caribaea*), and most of the mining pits have now been filled in by the forestry company for reasons of safety. However, forest rangers were still able to lead us to several known, open pits that were relatively easy to get to through the densely wooded and steep hillside (KYS118). We were informed that there were three further areas of such un-filled *enambo* within the range of the commercial forest, yet we didn't ground-truth this due to the difficulty of reaching them. A network of streams, watercourses and marshes (Wafuba, Kanywankoko, Kisunu, Bwijanampiri, Nyabukani) also ran close to the site.

EXCAVATIONS

Two aspects of the site at Kyakaturi were targeted for excavation (*cf.* Figure 5.2): the furnace remains, and the main compound slag scatter, where a single exploratory testpit (one metre by one metre) was excavated.

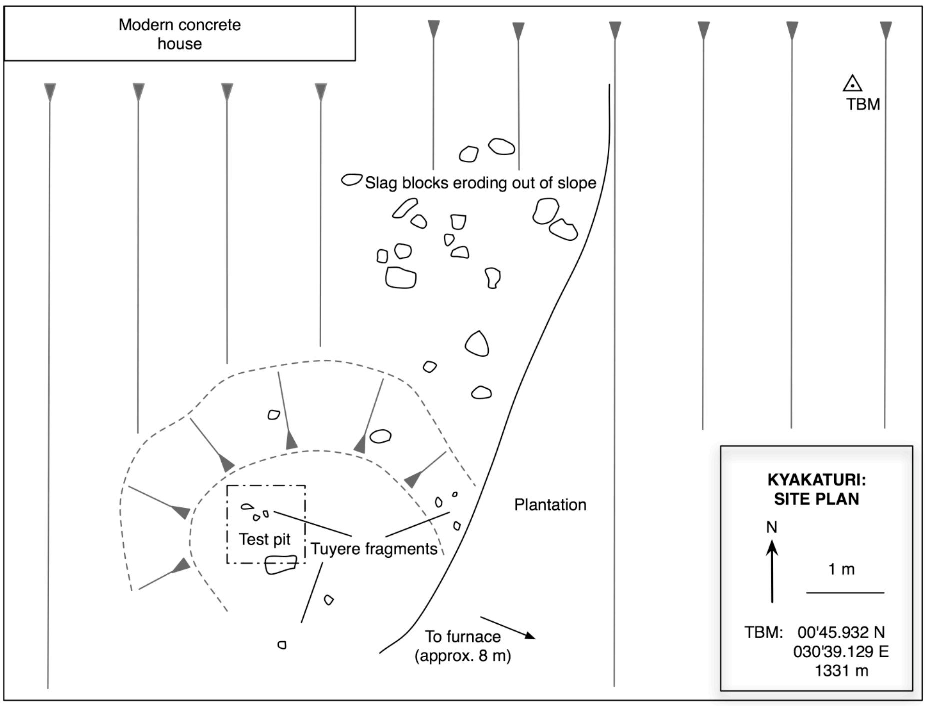


Figure 5.2 Site plan of Kyakaturi

The furnace was initially indicated by a faint circle of hardened furnace wall and the top of a slag block, protruding from the compacted soil of the path (see Figure 5.3

below). Excavation revealed that the shallow furnace pit was almost entirely filled with a single, large, in-situ slag block (Figure 5.4).

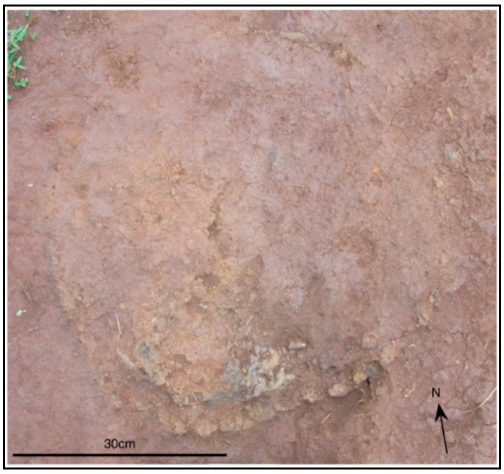


Figure 5.3 Furnace at Kyakaturi, pre-excavation

Figure 5.4 In-situ slag block in furnace, Kyakaturi

Above the slag block, the fill was somewhat mixed (Figure 5.5). The top few centimetres were primarily composed of a highly compacted red silty clay, comparable to that of the surrounding path matrix, and this blended into a more friable dark reddish brown fill (077). The large slag block, and correspondingly low volume of fill meant that there was very little space for additional finds, which comprised solely 20g of slag fragments and occasional pieces of broken furnace wall.

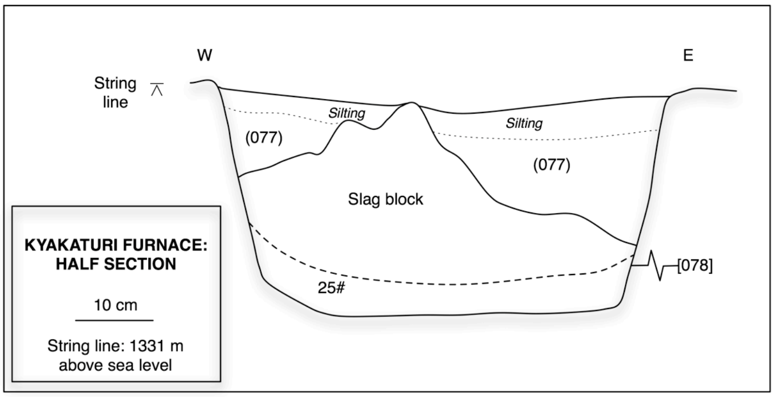


Figure 5.5 Composite profile of half-sectioned furnace at Kyakaturi, with in-situ slag block. In this and future furnace sections, the location of the charcoal sample(s) taken for radiocarbon dating is marked with 'x#'. This (and many of those that follow) is a composite diagram, combining two section drawings – one drawn prior to and one drawn after slag block removal – to best demonstrate the structure of the furnace fill and the shape of the furnace pit

The surviving furnace pit itself was circular in plan and 50cm in diameter, with slightly sloped sides to a depth of approximately 30cm. Beneath the slag block, the extent of the furnace base – unlined and presumably unexposed to the high temperatures that would have affected the upper parts of the furnace wall – was defined by the transition between loose, dark red charcoal-rich fill and bright red natural clay.

A fragment of charcoal that had been recovered from beneath the in-situ slag block (*cf.* Figure 5.5) generated a radiocarbon date of 625 ±26 BP, which calibrates to 1290-1398 cal. AD with a 95.4% probability (OxCal 4.1; IntCal09; Bronk Ramsey 2009; Reimer *et al.* 2009). This dates this secure context, and as such the smelting episode under examination, to roughly the fourteenth century.

Whilst excavation of the furnace pit was taking place, excavation of the testpit within the neighbouring compound was also under way, in conjunction with the recording and sampling of individual slag blocks from that localised area. No features were identified within the testpit, which revealed only a shallow, mixed deposit (heavily disturbed by burrowing animals) on top of the red natural clay. However, a high density of finds were removed from this relatively thin deposit (c. 10cm deep), including approximately 200g of tuyère fragments and 250g of slag fragments, as well as some domestic pottery, including one sherd with highly eroded knotted-strip roulette decoration.

As the buried and half-buried slag blocks were distributed across the full extent of the compound floor, it would have been impossible to confidently estimate the full number of them without causing significant disruption to the family who lived there, although I would suggest that there are unlikely to be more than 70 slag blocks in the immediate vicinity. However, sixteen easily accessible slag blocks from an area approximately 2-3m to the northeast of the testpit were recorded individually and sampled. The slag block that was removed from the furnace base was also recorded and sampled in the same way.

Unfortunately, it is not possible to categorically link the slag blocks to the dated furnace, but due to the similarities in the macroscopic features and the chemical compositions in the slag samples (outlined in the following sections), it can be posited that the smelting episodes represented in the slag blocks all originate from the same period. The relatively small amount of smelting activity (at least that was indicated by the smelting remains) is potentially associated with one individual leading several smelts over a relatively short period of time, although it is difficult to say this with any certainty as removal of slag blocks from the site may have happened over the preceding centuries.

ANALYTICAL RESULTS AND INTERPRETATION

TECHNICAL CERAMIC ANALYSES

Numerous tuyères were found at surface level at and around the site of Kyakaturi, and many were also excavated from the testpit. None were recovered from the limited fill of the furnace pit, which unfortunately precluded making a definitive association between the tuyères that were to be analysed and both the smelting technology represented in the slag blocks and the radiocarbon date of the furnace. Macroscopic descriptions and dimensions were recorded of all recovered tuyères (*cf.* Appendix E).

The tuyères found at Kyakaturi ranged in colour from dark grey to mid-orange (Figure 5.6). Fragments were recovered that were from the flared, trumpet-shaped end of the tuyères (that would have received the spout of the bellows outside the furnace); several were also found in large pieces (e.g. Figure 5.7), indicating the tubular shape of the complete tuyères.

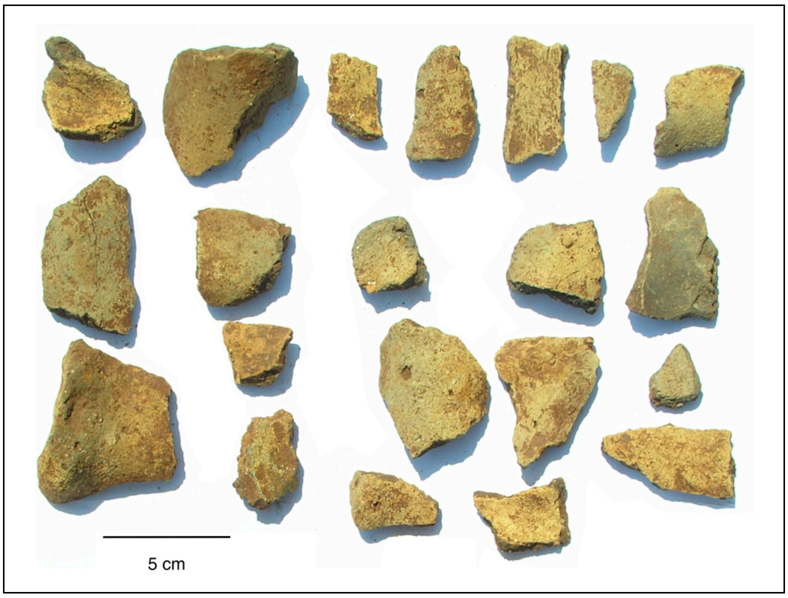


Figure 5.6 Examples of tuyère fragments excavated from Kyakaturi, context (080)

Several macroscopic indications pointed to the method of manufacture of these ceramics. From the continuous, parallel, longitudinal striations that are visible along many of the interior surfaces of the tuyères, it seems that they were formed around a stick. This practice has been widely documented ethnographically, such as in the example of the Haya in Tanzania, who form their tuyères around wooden 'dowels' or 'mandrels' before leaving them to dry (Todd and Charles 1978: 64; Childs 1988: 15; Schmidt 1997: 63; Figure 5.8). The average internal diameter (bore size) of all the recovered tuyère fragments was 4.0cm, and the average thickness of the tuyère walls was 1.0cm.

Figure 5.7 Example of single tuyère fragment excavated from Kyakaturi, context (080)

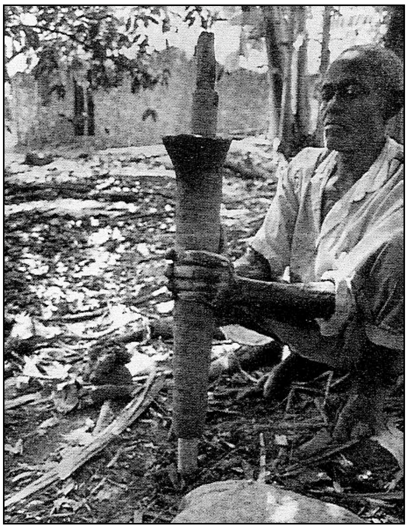


Figure 5.8 Tuyère being formed around a mandrel, with ash used as a lubricant (from Schmidt 1997: 63). Note flared end at top of tuyère

Bulk chemical analysis (PED-XRF) was undertaken on two excavated samples, one predominantly grey in colour and one predominantly orange. A sample of the furnace lining was also analysed in this way. Both of the tuyère samples that were analysed by PED-XRF were also studied using reflected light microscopy and SEM-EDS. In addition to this, a single example of domestic pottery was chemically analysed using PED-XRF, to provide a comparison to the clay that had been selected for the tuyères (Figure 5.9).

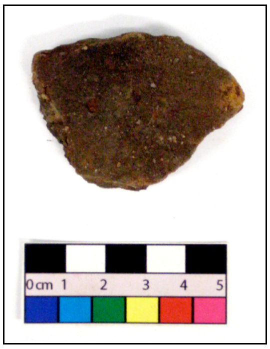


Figure 5.9 Analysed pottery, surface find, Kyakaturi

An assessment of the resultant data was made in order to ascertain whether there were any specific criteria surrounding the selection of clays and preparation of the technical ceramics. The suitability of these materials and how they would have performed in these smelts was also assessed, alongside a general characterisation of their manufacture and use. By comparing the compositional data from the tuyères with that of the domestic pottery, it was possible to discuss whether the procurement of raw materials and the preparation of the clays differed in any way for these two types of ceramic.

From a macroscopic inspection, both examples of tuyère seemed relatively coarse with large quartz inclusions. One sample – Tuyère A – contained a much higher proportion of quartz than Tuyère B. Once the samples were cut to prepare them for mounting and polishing, it became clear that Tuyère A also contained large grog inclusions. These observations were confirmed through the optical microscopy (Figures 5.10 and 5.11).

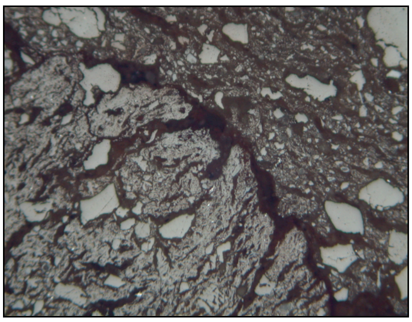


Figure 5.10 Tuyère A, Kyakaturi, showing frequent quartz inclusions and the edge of a large grog inclusion. The top right of the image is the tuyère fabric; the bottom left comprises a grog inclusion. Image width ≈ 1mm; PPL

The quartz inclusions in Tuyère A were not regularly sized, ranging from <0.05mm to 0.3mm, but their pervasive presence (covering an estimated 20% of the sample area) is suggestive of a deliberate addition of quartz to the clay paste. The quartz inclusions in Tuyère B were more regular in size (approximately 0.05mm to 0.2mm) covering around 10-15area%, and in this tuyère sample there were no grog inclusions.

The domestic pottery example showed a comparable amount of quartz inclusions, but these tended to be larger and more irregularly spaced across the sample surface area (Figure 5.12). No grog temper was apparent.

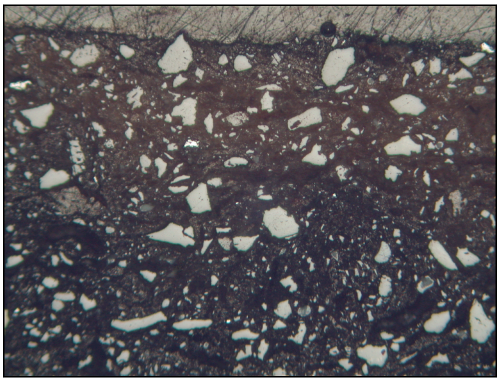


Figure 5.11 Tuyère B, Kyakaturi, showing frequent quartz inclusions. Image width ≈ 2mm; PPL

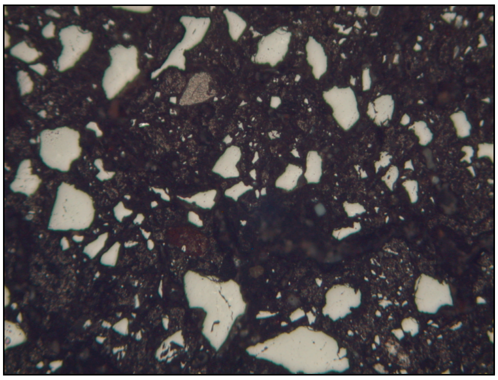


Figure 5.12 Surface pot, Kyakaturi. Image width ≈ 2mm; PPL

The angular and elongated porosity running parallel to the tuyère surfaces is indicative of their method of manufacture – smearing clay around a stick with a large quantity of quartz – and the porosity itself, like the addition of quartz temper, would have improved the toughness and thermal shock resistance of these technical ceramics (Rye 1981; Childs 1988, 1989; Freestone and Tite 1986). The directional nature of this porosity is most clearly illustrated in Figure 5.10, where it contrasts strongly with the direction of the porosity in the grog inclusion. Neither Tuyère A nor Tuyère B showed any visible signs of bloating or vitrification, and there were only a few examples of cracked quartz, which would have been a further indicator of exposure to high temperatures, however these samples were chosen precisely due to the lack of external signs of vitrification (*cf.* Chapter 4), and there were vitrified fragments of tuyères at this site.

The PED-XRF analyses, as shown below in Table 5.1, and as reported in full in Appendix F, reflect the high levels of quartz observed macro- and microscopically. Both contain on average 73wt% silica, and from 19wt% (Tuyère A) to 21wt% (Tuyère B) alumina. This gives an alumina to silica ratio of approximately 1:3.5. The compositions of both tuyères are also very similar, with no significant variation in either major or minor compounds. Slightly more variation occurs in barium oxide and the rare earth elements, with Tuyère B showing the highest levels of all, corresponding to a relatively lower dilution by silica (quartz).

	Major and minor compounds													
KYAKATURI (KTR)	Na_2O wt%	MgO wt%	Al_2O_3 wt%	*SiO_2* *wt%*	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
				original	adjusted									
Furnace slag M	0.24	0.37	6.32	*30.69*	30.38	1.49	0.05	1.29	3.79	0.34	0.04	0.10	0.89	53.58
Furnace slag B	0.30	0.25	4.62	*30.60*	30.29	1.54	0.07	1.06	2.22	0.23	0.04	0.15	0.86	57.43
Slag 1 M	0.24	0.18	7.48	*30.77*	30.46	1.39	0.06	1.00	1.11	0.50	0.05	0.07	0.53	56.14
Slag 2 M	0.27	0.31	8.56	*33.40*	33.40	1.16	0.05	1.69	2.73	0.50	0.05	0.12	0.63	50.15
Slag 6 T	0.18	0.32	6.67	*27.24*	25.06	1.75	0.10	1.41	3.58	0.35	0.04	0.15	0.97	56.66
Slag 6 B	0.27	0.34	8.12	*32.14*	32.14	1.38	0.04	1.39	3.92	0.42	0.03	0.08	0.86	50.50
Slag 7 B	0.21	0.18	7.66	*31.09*	30.78	1.81	0.08	1.61	2.89	0.42	0.03	0.08	1.70	51.72
Slag 8 M	0.31	0.23	7.80	*30.34*	29.43	1.53	0.08	1.57	2.18	0.38	0.04	0.08	0.89	53.95
Slag 9 M	0.21	0.22	6.77	*30.52*	29.91	1.75	0.08	1.47	1.96	0.41	0.03	0.08	0.63	55.32
Slag 10 T	0.24	0.25	7.98	*30.26*	29.35	1.48	0.09	1.72	2.99	0.55	0.04	0.10	1.11	52.72
Slag 10 M	≤0.28	0.26	6.28	*25.37*	22.58	1.53	0.07	1.10	2.24	0.40	0.06	0.13	1.36	60.68
Slag 10 B	0.23	0.32	7.74	*32.40*	32.40	1.10	0.05	1.39	2.63	0.48	0.05	0.12	0.72	52.40
Slag 11 M	0.19	0.33	7.82	*29.13*	27.67	1.36	0.06	1.42	2.07	0.42	0.07	0.18	0.99	55.66
Slag 16 M	≤0.20	0.28	8.91	*39.02*	39.02	1.29	0.07	1.80	3.74	0.44	0.04	0.11	0.90	42.68
Ore (from furnace)	/	/	3.18	*3.73*	2.54	1.39	0.07	0.07	0.05	0.16	0.04	0.11	0.49	89.98
Vitrified quartzite	0.42	/	1.19	*92.05*	92.05	0.04	0.02	0.20	0.15	0.06	/	0.01	0.06	5.75
Tuyère A	≤0.40	≤0.14	18.58	*75.23*	75.23	/	0.05	1.80	0.15	1.05	/	0.01	0.02	2.54
Tuyère B	≤0.36	0.35	21.42	*71.56*	71.56	/	0.06	1.93	0.24	1.19	0.00	0.01	0.02	2.69
Furnace Wall	0.17	≤0.05	30.66	*43.27*	43.27	0.12	0.08	0.19	0.06	2.19	0.07	0.03	0.46	22.43
Surface Pot	0.21	0.22	21.70	*71.71*	71.71	0.03	0.07	1.98	0.17	0.93	/	0.01	0.03	2.75

	Trace compounds													
KYAKATURI (KTR)	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	Rb_2O ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	Nb_2O_5 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Furnace slag M	585	/	319	84	/	691	82	482	/	3157	1111	812	723	108.50
Furnace slag B	822	/	397	91	/	469	57	363	/	2380	833	629	551	108.47
Slag 1 M	821	/	412	65	/	280	74	605	/	1044	515	880	105	108.60
Slag 2 M	869	/	233	49	/	299	51	317	/	1337	251	327	≤96	110.72
Slag 6 T	663	/	293	44	/	561	66	500	/	2040	500	683	330	110.19
Slag 6 B	585	/	230	54	/	525	59	475	/	1958	401	569	269	108.89
Slag 7 B	374	/	174	55	/	418	64	477	/	2497	387	601	197	108.42
Slag 8 M	685	/	282	46	/	409	69	551	/	2401	513	849	316	107.26
Slag 9 M	681	/	401	65	/	363	73	527	/	1643	523	908	252	108.25
Slag 10 T	644	/	219	38	/	350	52	426	/	1808	341	444	288	109.70
Slag 10 M	659	/	385	53	/	226	38	306	/	1169	202	246	/	109.33
Slag 10 B	673	/	297	64	/	297	45	320	/	1419	273	342	≤72	109.68
Slag 11 M	686	/	226	38	/	191	35	275	/	1285	193	310	/	109.30
Slag 16 M	468	/	141	48	/	510	65	441	/	3073	318	420	330	109.08
Ore (from furnace)	910	/	84	258	/	127	/	788	/	456	2348	1090	1044	98.71
Vitrified quartzite	104	7	33	17	7	27	/	60	41	129	33	≤38	59	107.98
Tuyère A	47	29	34	95	77	49	/	714	51	552	114	193	136	98.18
Tuyère B	54	45	45	61	96	62	/	808	52	866	199	290	226	94.35
Furnace Wall	411	68	219	145	31	3	/	728	40	286	120	304	114	82.75
Surface Pot	53	40	64	50	123	31	/	589	50	449	131	206	≤176	93.85

Table 5.1 PED-XRF compositional data for all samples from Kyakaturi, normalised to 100%. All values are the average of the three analyses of each sample reported in Appendix F. 'Analytical total' shows the analytical total prior to normalisation. In this and following compositional tables, 'T' indicates top sample; 'M' indicates middle sample; and 'B' indicates bottom sample of a slag block. Values of zero are reported as such; values below the detection limits of the PED-XRF in all three analyses are reported as '/'. Values of three analyses where some are below detection limits and others are successfully measured are reported as less than or equal to the average of the successfully measured values

The line plots below demonstrate just how closely matched the two tuyère compositions are (in blue), especially with regards to the major and minor compounds (Figure 5.13).

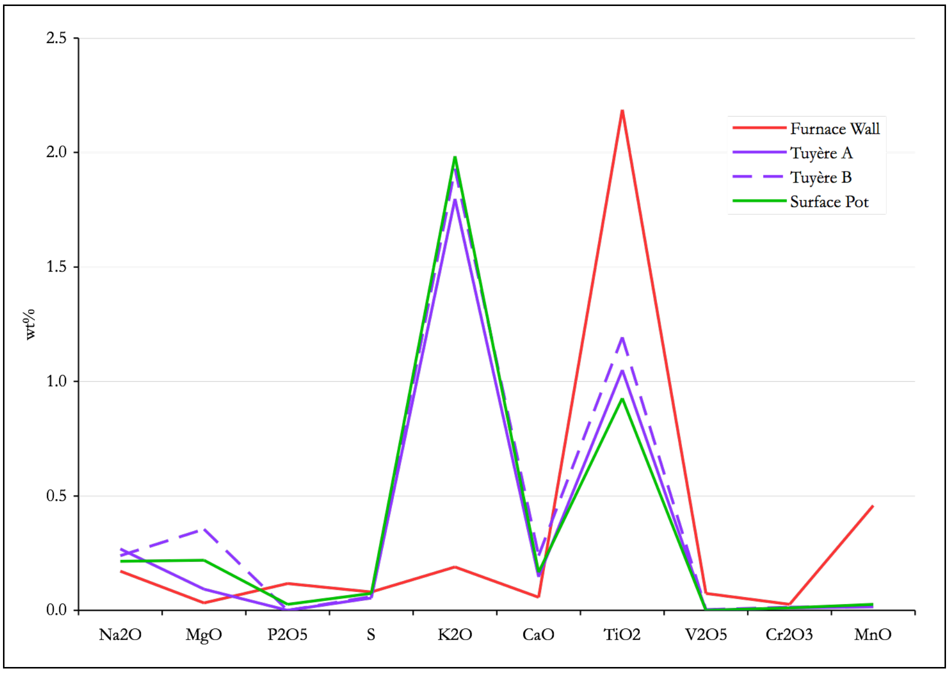


Figure 5.13 Line plot showing major and minor compounds (less Al_2O_3, SiO_2, FeO) of all analysed ceramics from Kyakaturi, calculated from PED-XRF data normalised to 100%

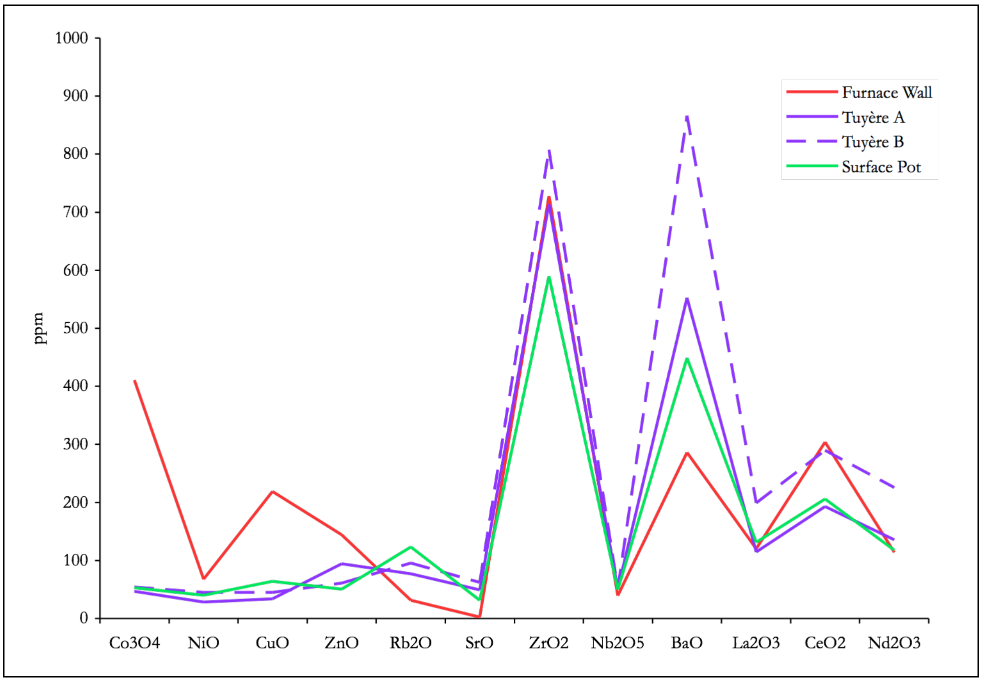


Figure 5.14 Line plot showing trace compounds of all analysed ceramics from Kyakaturi, calculated from PED-XRF data normalised to 100%

The sample of domestic pot also seems to be made from a clay with a near identical chemical signature to that of the tuyères, and they map very closely together on the ternary diagram below (Figure 5.15). Indeed, the second tuyère sample is obscured by the domestic pottery sample in this graph.

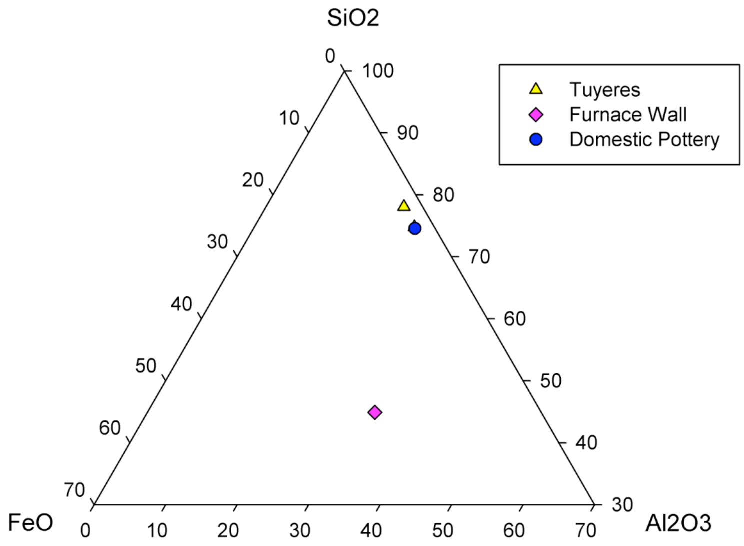


Figure 5.15 Truncated ternary diagram showing the chemical composition of tuyères, furnace wall and domestic pottery samples from Kyakaturi. Calculated from PED-XRF data, normalised to 100%

The furnace wall sample is spatially removed from the other samples in Figure 5.15. The high iron oxide level in this sample suggests that it may have been distorted by its proximity to the furnace charge or tempered with crushed slag. An examination of a fragment of crushed furnace wall suggests that the latter may be the case in this instance. Quartz temper was not apparent, which would fit also with the low silica levels. Due to the iron oxide content, unfortunately there are few conclusions we can draw from the bulk analyses of this sample as to the original composition of the clay used in the furnace wall lining. However, when taking the dilution factor of the iron oxide into account, the alumina still remains relatively high, and so it can be suggested that the clay for the furnace wall would have been similarly refractory to that used in the manufacture of the tuyères.

SEM-EDS microanalysis of the ceramic matrix of the tuyères, from areas free from inclusions, reinforced the alumina-rich nature of this material (Table 5.2). The ratios of alumina to silica of these samples (1:1.9 and 1:1.6) are now much more in keeping with the alumina to silica ratio of the furnace wall sample (1:1.5), which suggests that the clay for the furnace wall may also have derived from the same source, but with different tempering approaches.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	FeO	BaO	(wt%)
Tuyère A	0.3	/	32.2	60.6	0.3	0.9	0.4	1.3	4.1	/	
Tuyère B	0.2	0.6	34.4	56.2	0.3	1.0	0.4	1.9	4.9	0.1	

Table 5.2 Averaged SEM-EDS compositional data for both tuyères from Kyakaturi, normalised to 100%

The SEM-EDS microanalysis was also able to identify several of the smaller mineral inclusions in the fabric of the tuyères besides the ubiquitous quartz. As well as frequent inclusions of feldspars and iron-rich pyroxenes, occasional ilmenite crystals were also present.

To summarise, the above analyses have indicated that a similar clay source was probably being used for all the fired ceramics under examination, and a similar clay source was also likely used for the furnace lining. Although only a very limited number of samples were examined, it is interesting to note that not only is it likely that the same clay source was being utilised for both the tuyères and the domestic pottery for the area, they were being tempered in a similar way, with a large amount of added quartz. There was however, variation in grog tempering, and the furnace wall was possibly tempered with crushed slag, and not quartz. Nevertheless, the highly refractory nature of this clay suggests that the tuyères and/or furnace lining would have contributed relatively little ceramic material to the melt.

METALLURGICAL ANALYSES

MACRO-DESCRIPTIONS

The slag that was analysed from Kyakaturi was sampled primarily from the scatter of slag blocks that littered the compound floor (*cf.* Figure 5.2). Sixteen of the largest and most complete slag blocks were recorded in detail (Table 5.3), and several of these were selected for further analysis. Two of these had multiple samples taken from them: Slag 10 had samples taken from the top, middle and bottom of the slag block, in order to investigate the variation that occurred within the single smelting episode that had produced it; Slag 6 had two samples taken from it – one from a greyish area, and one from a greenish area, in order to investigate the cause of the green colouring of these blocks. The single large slag block excavated from the furnace was also sampled.

All of the slag collected from Kyakaturi appeared on a macroscopic level to be non-tapped furnace slag, produced by iron smelting activity. The slag blocks from the compound bore similarities in size, shape and colour to that excavated from the furnace base (Table 5.3 and Figure 5.16, see also Figure 5.4). From these macroscopic morphological similarities, I would suggest that the slag blocks that were sampled were the result of a very similar technological procedure in terms of furnace construction and shape, and technical operation.

	Complete	Width a	Width b	Depth	Weight	Samples				
Slag #	block?	cms	cms	cms	kg	Top	Middle	Bottom	ED-XRF	OM/SEM-EDS
1	N	51	43	15	45		✔		✔	✔
2	N	35	33	14	30	✔	✔	✔	✔	
3	N	28	32	17	16		✔			
4	N	33	40	15	19		✔			
5	N	34	26	13	23	✔	✔	✔		
6	N	50	36	20	29	✔		✔	✔	
7	N	32	23	16	21	✔		✔	✔	
8	N	38	32	15	24		✔		✔	
9	N	29	16	15	12		✔		✔	
10	N	16	32	15	31	✔	✔	✔	✔	
11	N	47	26	17	33		✔		✔	
12	N	48	40	21	47	✔		✔		
13	N	33	25	14	20		✔			
14	N	23	21	10	10		✔			
15	N	31	17	10	10		✔			
16	N	22	13	7	7		✔		✔	✔
Furnace	Y	53	53	23	78		✔	✔	✔	✔

Table 5.3 Summary of macroscopic information recorded for the slag blocks from Kyakaturi

Although none of the slag blocks from the compound cluster were complete – with all showing at least one fractured edge – many of them had flattened bases, which had apparently cooled against the surface of a bowl-like furnace base. Impressions of small to medium reeds and grasses were present in and on most blocks, especially on and in the lower portions of the slag blocks. Very occasionally, sedge impressions with a triangular-profile were also apparent.

Figure 5.16 Large, single slag block excavated from the furnace at Kyakaturi (upside down). Scale bar is 30cm

Most of the slag blocks were bluish-green grey in colour, and they ranged considerably in weight. The complete slag block from the furnace was particularly large and heavy, weighing almost 80kg. The other slag blocks were lighter, but as mentioned previously, these were fractured parts from originally larger slag blocks. However, all the blocks from this site tended to be relatively dense in comparison to slag from other sites, and very difficult to break with a sledgehammer for sampling. The typically solid, non-porous nature of all these slag blocks is suggestive of a slag melt that ran into the furnace base fluidly during the smelts that created them.

ANALYSIS

The PED-XRF results, presented in Table 5.1 and reported in full in Appendix F, were consistent with all the slag samples being bloomery slag, composed primarily of silica and iron oxide. The major components of silica, alumina and iron varied very little, with silica averaging 30wt%, alumina averaging 7wt% and iron oxide averaging 54wt%. There were some outliers, of which Slag 16 was the most obvious, with a low iron oxide reading (43wt%) contrasting with elevated silica (39wt%) and alumina (9wt%) levels. The ratio of alumina to silica averages at approximately 1:4, with an outlying figure of 1:7 from the bottom sample of the furnace slag due to the low alumina levels of this sample.

Minor and trace compounds were also fairly consistent across the sample set (*cf.* Table 5.1 and Figure 5.17). The levels of the other minor compounds are not on the whole unusual, although there are moderate levels of lime, which rarely falls beneath 2wt%.

Manganese oxide tends to be relatively low in all samples, at below 1wt% (Pleiner 2000: 252), although this appears to be unusual for the area as a whole (see rest of this chapter and Chapter 6). Phosphate was notably and consistently high (1.10-1.81wt%), which if present in such high quantities is usually suggested to derive in the main from the ore (Pleiner 2000), although phosphate is also present in fuel ash; this (and its implications) will be discussed later in the chapter.

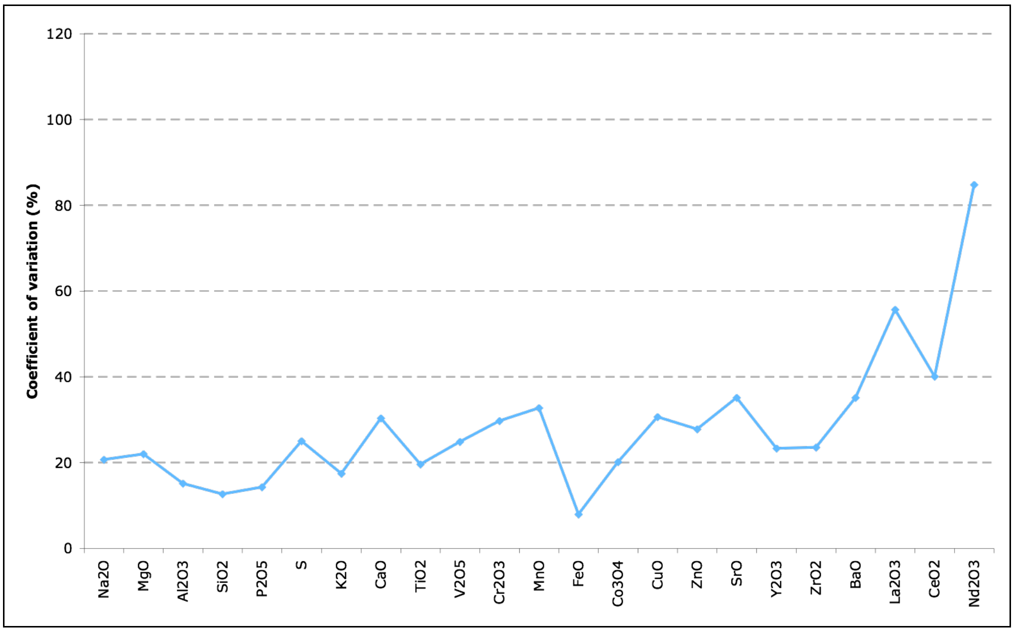


Figure 5.17 Coefficient of variation for all compounds in the sampled slag blocks from Kyakaturi, calculated from PED-XRF data normalised to 100%

Further to this, there are several elevated trace compounds worth mentioning. As well as the oxides of barium and some rare earth elements, levels of cobalt, copper and zinc oxides are all very high. In the high temperatures and strongly reducing atmosphere typical of the environment of an iron smelting furnace, these oxides are likely to have reduced to their constituent metals (*cf.* Ellingham diagram, Gilchrist 1989). The more volatile metals would thence have evaporated (Zn, with a boiling point of 907°C), whilst those less volatile would most likely have reduced into the iron metal rather than remain in the slag (Co, Cu) (Crew 2000; Desaulty *et al.* 2009). The fact that these metals remain in the slag in any quantity is probably testament to the high levels of them entering the smelt. This appears to be confirmed by the bulk chemical analysis of the ore: cobalt, zinc, lanthanum, cerium and neodymium oxides all register very high readings in this sample.

In order to assess the internal homogeneity or heterogeneity of the slag blocks, the three samples from the top, middle and bottom of Slag 10 were considered together. The analyses of these samples allowed for an examination of the extent of variation within the smelting episode, highlighting any changes in the smelting parameters through the course of the smelt, as well as providing an assessment of the level of representation that can be assumed from each single slag sample. There was found to be considerable variation in the contributing compounds to the slag block throughout the duration of this smelt (Figure 5.18). Of the major components of the slag, silica is the most variable, with a coefficient of variation (CV) of 18%, whereas the other major compounds – iron oxide and alumina – are less variable, at 8% and 13% respectively. Manganese oxide also shows a significant amount of variation (31%), yet the majority of compounds show a coefficient of variation of less than 20%. Taken together with the prior assumption that these slag blocks formed from reasonably fluid slag, and bearing in mind similar work undertaken by Jane Humphris (Humphris *et al.* 2009), this variation can be considered relatively low and the slag block relatively homogeneous.

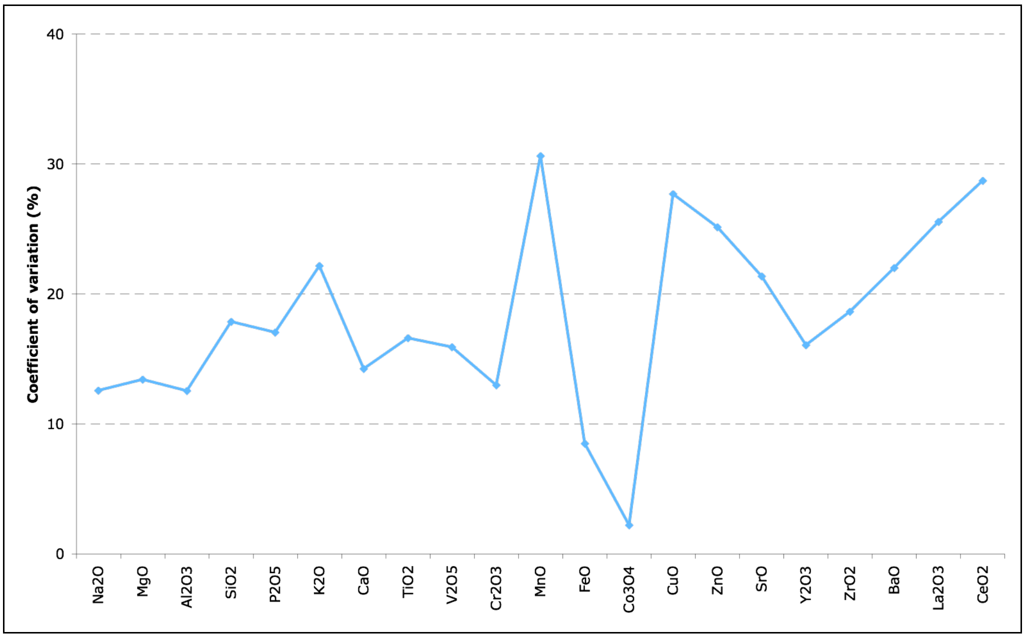


Figure 5.18 Coefficients of variation for all compounds through start-middle-end of a single smelt, calculated from three samples from Slag 10, Kyakaturi

In an attempt to understand the reason for this variation, the results for the beginning, middle and end of the smelts were examined in more detail. Several compounds that are potentially linked to the ore – manganese oxide, iron oxide, copper oxide and phosphate – were seen to rise during the middle of the smelt. Most of the other compounds show a dip during this time; silica shows a particularly dramatic dip (Table 5.4).

Kyakaturi	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	Co_3O_4 ppm	CuO ppm	ZnO ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm
Slag 10																							
Beginning	0.23	0.32	7.74	32.40	1.10	0.05	1.39	2.63	0.48	0.05	0.12	0.72	52.40	673	297	64	297	45	320	1419	273	342	24
Middle	0.19	0.26	6.28	22.58	1.53	0.07	1.10	2.24	0.40	0.06	0.13	1.36	60.68	659	385	53	226	38	306	1169	202	246	/
End	0.24	0.25	7.98	29.35	1.48	0.09	1.72	2.99	0.55	0.04	0.10	1.11	52.72	644	219	38	350	52	426	1808	341	444	288

Table 5.4 PED-XRF data for Slag 10, Kyakaturi, showing chemical composition for the beginning (bottom sample), middle (middle sample) and end (top sample) of the smelt. Those compounds that show a dip in the middle of the smelt are highlighted in yellow; those that rise in the middle of the smelt are highlighted in pink

This pattern seems to imply that something occurred to reduce the efficiency of the smelt during its middle stages. It might be that insufficient silica was entering the system at this time, which would have inhibited the extraction of iron from the ore minerals. Alternatively, perhaps the temperature or the reducing atmosphere at this time were not maintained at ideal levels.

Of the samples that were selected for further microscopic examination, the middle sample from Slag 1 (S1M) and the middle sample from the Furnace Slag (FSM) were very similar in microstructure, as would be expected from the bulk chemical analyses. Both were relatively homogeneous samples, comprising approximately 60area% fayalite, the blocky nature of which indicated a slow cooling time of the slag within the furnace. The SEM-EDS microanalyses showed that the fayalite is relatively pure Fe_2SiO_4, although there is some substitution of manganese (c. 1wt% MnO) and calcium (c. 1-2wt% CaO), and less commonly, magnesia for iron. The remaining area of these samples consisted of 30-35area% glassy matrix and 5-8area% pink, cubic spinels. SEM-EDS microanalysis determined these pinkish phases to comprise approximately 30-35wt% alumina, 3wt% titania and 65wt% iron oxide. This composition would place them within the solid solution/mixing series between magnetite ($FeO{\bullet}Fe_2O_3$) and hercynite ($FeO{\bullet}Al_2O_3$), with some Ti^{4+} substituting for alumina. Very little wüstite was present in either sample (<1area%), and there were also infrequent droplets of iron metal (Figures 5.19 and 5.20).

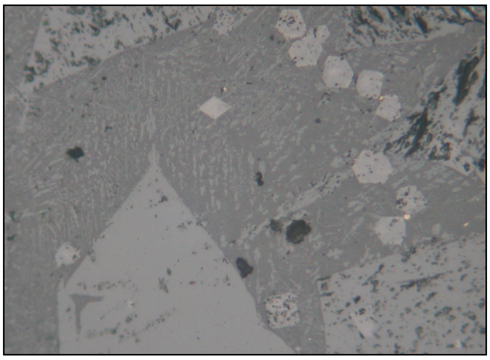


Figure 5.19 Photomicrograph of FSM, Kyakaturi, showing blocky fayalite (light grey), magnetitic hercynite spinels (pink, hexagonal) and the glassy matrix (dark grey). Image width ≈ 0.4mm; PPL

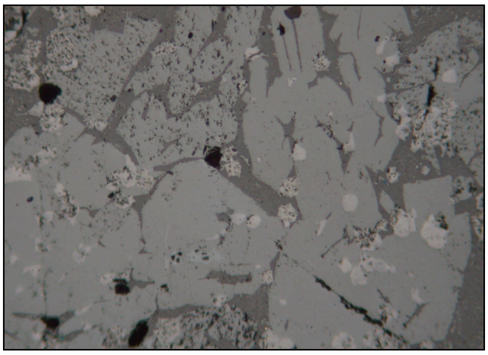


Figure 5.20 Photomicrograph of S1M, Kyakaturi, showing blocky fayalite (light grey), magnetitic hercynite spinels (pink, hexagonal) and the glassy matrix (dark grey). Image width ≈ 0.4mm; PPL

The presence of this magnetitic hercynite is not typical in bloomery iron smelting, as it forms from Fe^{3+} – an ion incompatible to combine into fayalite. As such, this would have been one of the final residual phases to form as the slag cooled and solidified, and may indicate that these slag blocks formed in conditions that were not strongly reducing (Th. Rehren pers. comm. 2010). However, these phases are relatively infrequent and are very small (*cf.* Figure 5.20).

The calcio-olivinic glassy matrix in FSM (Figure 5.21) was observed to have acted as a reservoir for compounds such as alumina (14-15wt%), phosphate (2-3wt%), lime (c. 17wt%), titania (c. 1wt%) and potash (c. 1wt%). Clusters of dark-grey leucite (K_2O•Al_2O_3•$4SiO_2$) were observed to be growing out of the glassy matrix and lighter-grey phases (seen in BSE) forming in the areas around the glassy matrix were found to have concentrations of lime of around 12-13wt%, with levels of titania of about 5wt% and iron oxide of approximately 40wt%.

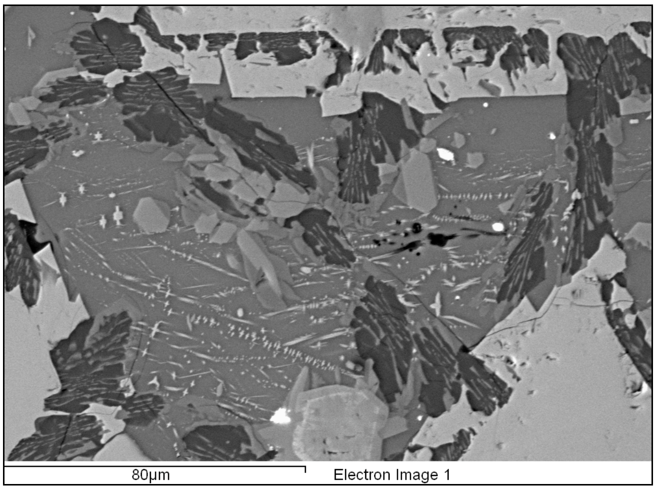


Figure 5.21 BSE image of FSM, Kyakaturi, showing developed fayalite (light grey), glassy matrix (mid dark grey) with exsolving fayalite, leucite (dark grey) and two-phased olivinic blocks (two-tone mid grey)

Sample S16M (Slag 16, middle sample) was similar in terms of phase proportions to samples S1M and FSM, but in general the size of the phases was smaller. The fayalite in this sample tended to be more elongated and feathery (Figure 5.22), although there remained some areas where the fayalite was blocky. A clearly demarcated strip of fayalite with a spinifex texture was present running across the centre of the sample (Figure 5.23). This indicates that at one point the slag within the furnace would have cooled quickly, before another layer of slag (the blockier crystal structure of which indicates a slower cooling time) dripped on top of it. The lack of interaction between the two layers suggests that the smelt may have been temporarily interrupted.

Again, fayalite and glassy matrix dominated the sample, in fairly equal proportions, and there was very little, if any, wüstite. The glassy matrix was speckled with a lighter phase exsolving from it (Figure 5.24), which was determined by SEM-EDS microanalysis to be fayalite. Occasionally, small droplets of metallic iron were present, but these were very infrequent. Rare hercynitic phases were also apparent.

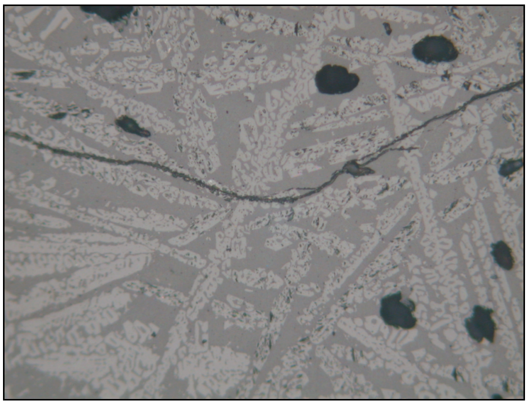


Figure 5.22 Photomicrograph of S16M, Kyakaturi, showing feathery fayalite (light grey), in a glassy matrix (dark grey). Image width ≈ 0.5mm; PPL

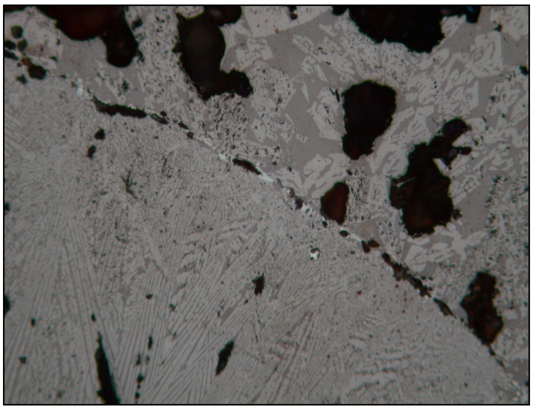


Figure 5.23 Photomicrograph of S16M, Kyakaturi, showing demarcation of change between feathery and blocky fayalite. Image width ≈ 1mm; PPL

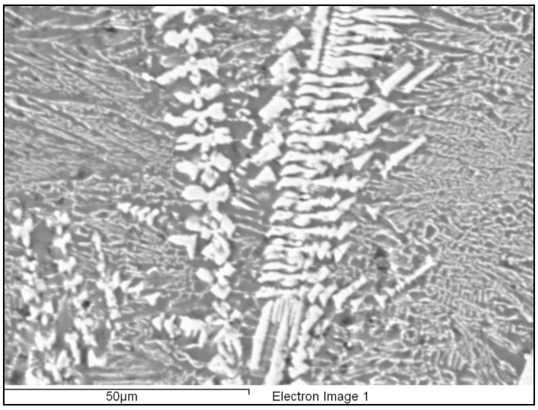


Figure 5.24 BSE image of S16M, Kyakaturi, showing fayalite (light grey) in the devitrified glassy matrix (dark grey)

A small fragment of unreduced ore was also excavated from the furnace pit at Kyakaturi and subsequently analysed using PED-XRF (Figure 5.25) The results of the bulk chemical analysis (*cf.* Table 5.1 and Appendix F) showed it to be a very rich ore, with an iron oxide (FeO) reading of nearly 90wt%. If this sample is representative of the ore used in these smelts, the associated low levels of gangue (3wt% alumina and 4wt% silica) would have required there to be a considerable contribution of silica from an alternative source in order for the smelt to be successful. As presented in the preceding section, this contribution is unlikely to have come from the highly refractory technical ceramics. A further notable aspect of the ore is the relatively high level of phosphate contained within it (c. 1.4wt%), corresponding with the phosphate in the slag. This may have had significant consequences for the iron that was produced from these smelts, as will be discussed in detail in the following section.

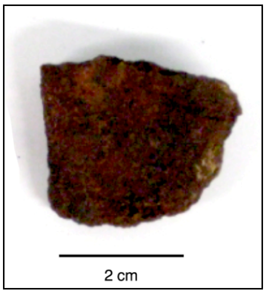


Figure 5.25 Fragment of unreduced ore, excavated from the furnace at Kyakaturi

DISCUSSION AND SUMMARY

By plotting the bulk compositional data generated from analysis of these slag blocks on a ternary phase diagram (iron oxide-silica-alumina) a further insight into the operation of these smelts was gained (Figure 5.26). From this diagram it is possible to suggest that these smelts operated at a minimum temperature of around 1100-1200°C, and the samples fall securely in the region of the phase diagram that is associated with the formation of fayalite, consistent with the results of the optical microscopy. A single outlier (Slag 16) falls significantly further towards the silica region of the diagram. With its location marginally closer to Optimum 1 (*cf.* Rehren *et al.* 2007), this slag would have formed either with a greater addition of a silica-rich material, or in more strongly reducing conditions than the other samples. Considering the information presented in the following paragraphs, I suggest that it is the former rather than the latter. Nevertheless, this slag block would have originated from a system with a slightly more efficient outcome than the other slag blocks at this site.

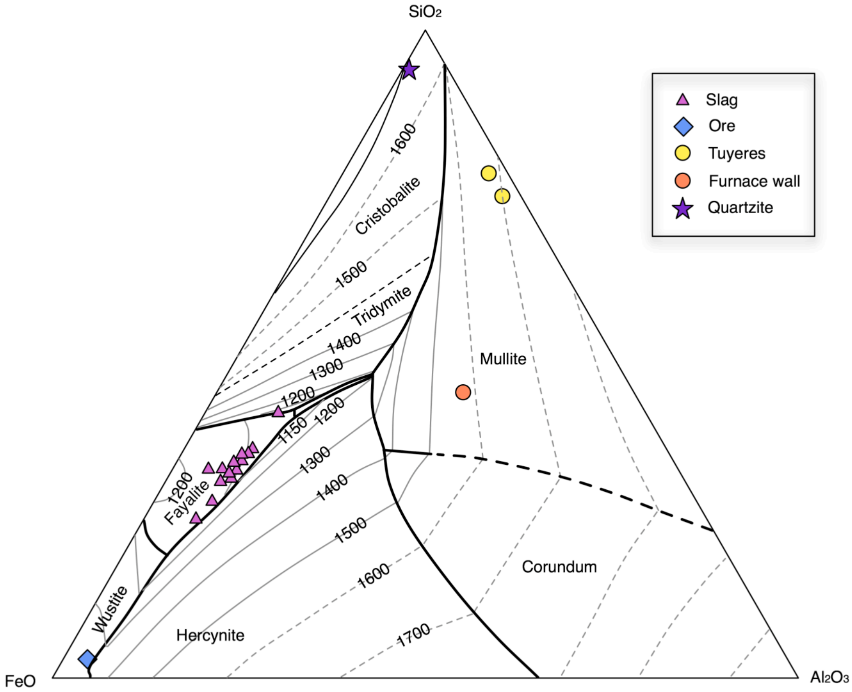


Figure 5.26 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO, with plots for all samples from Kyakaturi (phase diagram adapted from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%; slag samples are plotted in terms of Al_2O_3+TiO_2 – SiO_2 – FeO+MnO+CaO

If the relatively low minimum operating temperatures indicated by the phase diagram above are accurate, the contribution from the technical ceramics – bearing in mind their refractory nature – might indeed have been limited, as was suggested by the disparity between the alumina to silica ratios of the technical ceramics and the slag blocks. The alumina to silica ratios of the slag samples (averaging 1:4, but ranging up to 1:7) are somewhat lower than the alumina to silica ratios in the analysed technical ceramics (1:3.5). This indicates that extra silica is entering the system from a source other than the technical ceramics. The low silica levels in the small piece of unreduced ore that was recovered from the furnace fill and subsequently analysed (*cf.* Table 5.1), suggest that this was not the source of the additional silica.

Instead, the final material to be analysed and discussed in this section begins to look more interesting. A small fragment of an unusual, vitrified substance was excavated from the furnace pit, measuring approximately 2cm^3. With a red, vitrified crust, on cutting it for sampling, what looked like the structure of a metamorphic quartzitic rock was revealed (Figure 5.27). In order to determine what this material was, and to see if it had any relevance to the reconstruction of the smelting technology at Kyakaturi, it was analysed using PED-XRF (*cf.* Table 5.1 and Appendix F), and prepared for optical microscopy (Figure 5.28).

Figure 5.27 Quartzitic rock excavated from furnace, Kyakaturi

The PED-XRF analysis showed that it was composed primarily of silica, with 6wt% of FeO. This iron oxide content is likely to be related to the fact that the sample (which was very small) was prepared as a whole for analysis, including the vitrified outer crust, and is not necessarily representative of the central rock composition.

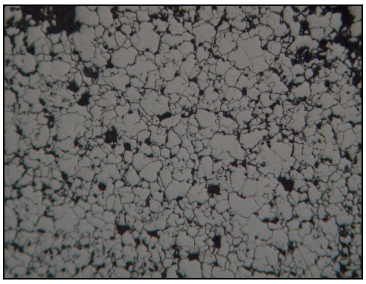


Figure 5.28 Photomicrograph of quartzitic rock excavated from furnace, Kyakaturi. Image width ≈ 2mm; PPL

Considering the refractory nature of the ceramics from this site, and their consequently small contribution to the melt, and also considering the low silica levels present in the ore sample, it is possible that this sample is a remnant of a flux that was added to the smelt in order to encourage the formation of a slag. The addition of quartzitic sand, although not common in the ethnographic literature, has been documented archaeometallurgically in Phalaborwa, South Africa (Miller *et al.* 2001), where rich magnetite ores with very little gangue were fluxed with sand from nearby riverbeds. If indeed this was also the case at Kyakaturi, it is likely that the quartzitic rock would have been crushed or powdered before being added to the smelt, increasing the surface area relative to the volume so that it could easily combine into the melt. The fact that this un-crushed fragment had managed to enter the smelt as a relatively large piece probably contributed to its survival, and allowed us the opportunity to glimpse this aspect of the technology.

The phosphoric nature of the ore was also of particular interest. Up to a quarter of the available phosphorous in an iron ore can partition to the iron metal (Tylecote 1987: 52), which in this instance would have resulted in iron with a phosphorous content of up to 0.15wt%. It would not have been possible to remove the phosphorous content of the ore before or during smelting; in order to avoid phosphorous enriched iron, the smelters would have had to avoid the phosphorous-rich iron ores. Phosphorous, like carbon, greatly increases the strength of bloomery iron and improves its work hardenability – at concentrations of approximately 0.5wt%, phosphorous-rich iron acquires the strength and hardness of a medium carbon steel (Rostoker and Bronson 1990) – yet at the same time it makes iron lose toughness and become brittle and less shock-resistant, especially at lower temperatures: it becomes 'cold short'. However, what is considered the limits of an acceptable phosphorous content in modern iron production (<0.04wt%) has not been agreed upon by past iron smelters, who in many situations successfully embraced what today would be termed high-phosphorous iron (Gouthama and Balasubramaniam 2003; see also Humphris 2010 for an example from the Great Lakes region). Furthermore, high phosphorous contents provide some extent of protection against corrosion, demonstrated most famously in the 1600 year-old Delhi iron pillar (e.g. Dillmann *et al.* 2002). Importantly, if the carbon content of the iron remains low, many of the negative effects attributed to high-phosphorous iron can be minimised, however this requires the air supply to be carefully controlled (*cf.* for example, Crew and Charlton 2007: 222; see also Godfrey *et al.* 2003).

As such, at the relatively low levels seen here, and depending on the intended use of the resulting iron, it is possible that the positive benefits of such a phosphorous content would be greater than any drawbacks, and the relatively warm ambient temperatures in this part of Uganda may have reduced any perceptible effect on brittleness. However, the smiths that worked with this iron would surely have been aware of the specific qualities of the iron from Kyakaturi, and as such it is relevant to consider the relative value of this iron as compared to other sources of iron in local markets.

The final remaining question to be addressed regarding this site concerned the greenish colour of the slag block. In order to assess the reason why this slag was such an unusual colour (compared to others in the region), two samples were taken from Slag 6: one from a greenish area (from the base of the slag block), and the other from a predominantly grey area (from the upper portion of the slag block). Unfortunately, the results of the bulk chemical analysis of these samples mirrored the variation observed in the three samples from Slag 10 (*cf.* Table 5.1), and as such, a meaningful pattern relating to this specific question could not be determined through these means.

Nevertheless, despite this, two hypotheses could still be proposed for the unusual colouring: the elevated copper content of the slag (which may have weathered to a green colour on the outer surfaces), or the formation of a particularly green olivine within the slag. Two arguments were quickly found to negate the first option. Not only did the green colour extend within the slag once it was broken open (reducing the likelihood that it was related to corrosion), many of the slag blocks from the wider region were found to have comparable (or higher) copper contents without displaying a greenish colour (*cf.* Rugombe, Part Three; Kirongo and Kisamura, Chapter 7).

This left only the second option: that of a dominating green olivine. The extensive presence of wüstite and small crystals of fayalite (which serve to break up and absorb the light) are what makes slag appear black. The low free-iron oxide content of these slag blocks (corresponding with relatively low bulk FeO contents) combined with relatively large fayalite crystals and high proportions of glassy matrix would encourage the slag to appear greenish in these instances rather than black. The mid dark grey glassy matrix seen in sample FSM (*cf.* Figure 5.21) had compositions approaching kirschsteinite – $CaFe^{2+}(SiO_4)$ – with a low iron oxide content (<20wt%, with alumina acting to replace some of the FeO); this would also have promoted a greyish-green colour throughout the slag. The presence of relatively high levels of phosphate may also have brought out the green aspects of the fayalite and the glassy matrix (Th. Rehren pers. comm. 2010). As such, this seems the most likely explanation as to the colouring of the slag blocks at this site.

To summarise, the analytical results presented here suggest the application of a single, repeated smelting methodology at the site of Kyakaturi. The technology appears to respond to the specific demands of local materials: the combination of highly refractory clays and an iron-rich ore necessitated the addition of a crushed quartzitic flux to enable slag formation. The addition of this further material into the furnace might have caused increased scope for variation between smelts; however, in the most part, the slag blocks (and thus the smelting episodes they represent) remain notably uniform. This in itself suggests that tight control was maintained over the operation of these smelts, prompting thoughts of a highly regulated local production industry in this area in the fourteenth century.

PART TWO: MIRONGO (MNG)

c. 14th century (1314-1430 cal. AD)

SITE DESCRIPTION

The second site to be introduced in this chapter is the site of Mirongo. The modern village of Mirongo is situated approximately 15km due west of Kyenjojo, within the jurisdiction of Butiti sub-county headquarters. The archaeological remains presented here (survey site KYS8) are located approximately half a kilometre to the northeast of the trading centre, within the hamlet of Kyangabukama, along the road towards Kasoga (where a further slag site was found – KYS115). Several other concentrations of slag blocks were found across the wider Mirongo area (including KYS9, KYS10, KYS97); this was clearly a region that had in the past produced a large volume of iron. Perhaps significantly, the Lunyoro word *mirongo* is the name of one of the three types of tree that Roscoe (1923: 218) notes as being specifically used to prepare charcoal for the Nyoro iron smelting technologies that he documented around Hoima. If the name Mirongo, as given to the trading centre, can be used to indicate the presence of high-quality *mirongo* wood for charcoal, this could conceivably be an important contributing factor towards the clearly considerable scale of smelting activity in the area.

The smelting site at Mirongo is within the main cluster of central Mwenge iron production sites that were selected for excavation, chosen due to the presence of a number of furnace bases at the site, and for the presence of several slag block clusters in the immediate area (Figure 5.29). The site consists of a number of furnace base remains in a road surface, along with several substantial scatters of slag blocks. These furnace remains and accompanying slag clusters were situated on the side of a moderate southwest facing slope, around which the road curves. A nearby compound – to the northeast of the main archaeological remains – was found to be richly spread with a layer of broken slag fragments, concentrated within a lens of dark and ashy soil. Several nearby ore mining locations were also found during the survey (e.g. KYS7), although none in the direct vicinity of the site; water is also accessible nearby, from small streams flowing into the larger watercourses and marshes of Nyabirubiko.

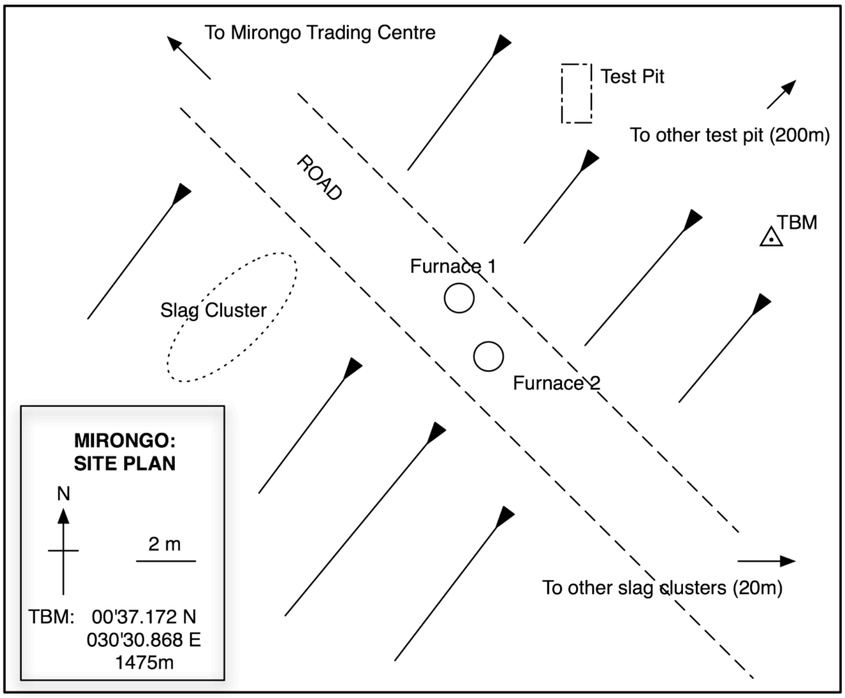


Figure 5.29 Site plan of Mirongo

EXCAVATIONS

One of the two visible furnace bases was excavated (Furnace 1, *cf.* Figure 5.30), along with two exploratory testpits, each measuring one metre by two metres; one was positioned close to the furnace base, directly above where the road had been cut, the other was situated in the nearby compound with dark ashy soils.

Figure 5.30 Furnace at Mirongo, prior to excavation

The upper context within the furnace consisted of a number of thin layers of mixed deposits, probably relating to various silting episodes after the furnace was abandoned. Half within these layers – and half within the more typical, ashy furnace fill below – sat a slag block, upright and potentially in-situ (Figure 5.31). This was above a second slag block, which had cooled against the furnace wall leaving a flattened edge, indicating that this second slag block was definitely related to the furnace.

Figure 5.31 Top of upper slag block at Mirongo, with lower slag block just visible beneath

The fully excavated furnace was approximately 75cm in diameter and 35cm deep, with a more gently sloped northwestern edge (or 'lip') in contrast to the near-vertical sides of the rest of the furnace circumference (*cf.* Figures 5.32 and 5.33).

Figure 5.32 Mirongo furnace fully excavated

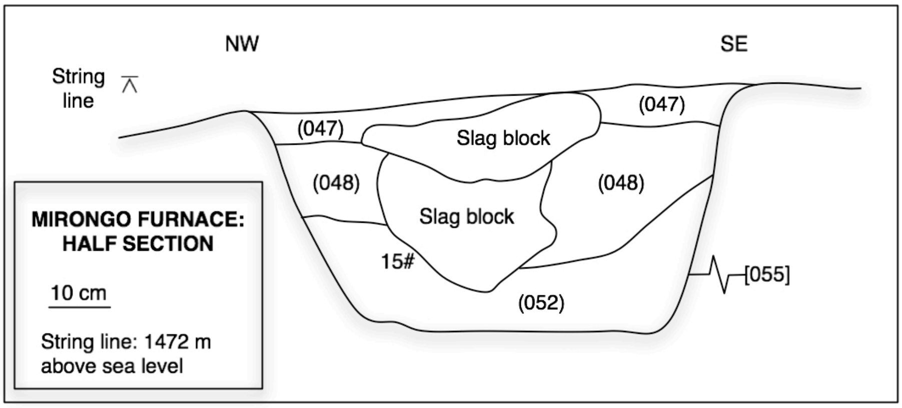


Figure 5.33 Composite profile of fully excavated furnace, Mirongo

The furnace base was dug through to confirm the absence of further archaeological deposits before the furnace was backfilled, and samples of tuyère, slag, furnace wall and charcoal were taken for analysis. Both of the two large slag blocks were recorded and sampled individually.

A sample of charcoal that was recovered from the lower context of the furnace fill, beneath the lower slag block (see Figure 5.33, marked 15#) generated a radiocarbon date of 553 ±27 BP, which calibrates to 1314-1430 cal. AD with a 95.4% probability (OxCal 4.1; IntCal09; Bronk Ramsey 2009; Reimer *et al.* 2009).

Excavating the furnace provided an excellent opportunity to consider how the furnace was used, and how the slag within it had formed. The two large blocks recovered from within the furnace both showed typical morphological signs of 'bloom formation' on the upper surface, namely raised circular texturing and high levels of orange ferric corrosion. Although not very similar in terms of chemical composition to the 'crown' material identified in Chirikure and Rehren (2006), especially in terms of iron oxide content (see later sites of Kirongo and Kisamura) it seems appropriate to use the term here as a best-fit description. The base of the upper block was very irregular and jagged, and petered out into brittle fragments, indicating that it had not formed against a solid, compacted furnace base, but that it had most likely cooled against looser soil and plant packing. The second slag block also had an irregular base, but part of it had cooled against the furnace wall, confirming its relationship with the furnace. The lack of a significantly fire-hardened furnace 'base' beneath the upper slag block, or alternatively the lack of any melding of the two slag blocks, contested earlier on-site discussions of the possibility that the two slag blocks were indicative of a re-use of the furnace base in two separate smelting episodes, yet the stratigraphy remained intriguing. An alternative explanation is that the slag block was placed within the furnace after it was abandoned, after which point context (047) built up around it.

Excavation of the testpits was undertaken concurrently with the excavation of the furnace base. The testpit closest to the furnace revealed part of a large pit or ditch, which contained a low to moderate density of slag fragments and undecorated domestic pottery (Figure 5.34). Although the relationship between this ditch and the furnace could not be determined stratigraphically – the testpit coming down onto natural at just over a metre above the upper surface of the furnace – an excavated potsherd from this feature was analysed to provide some extent of comparative data for the tuyère analysis.

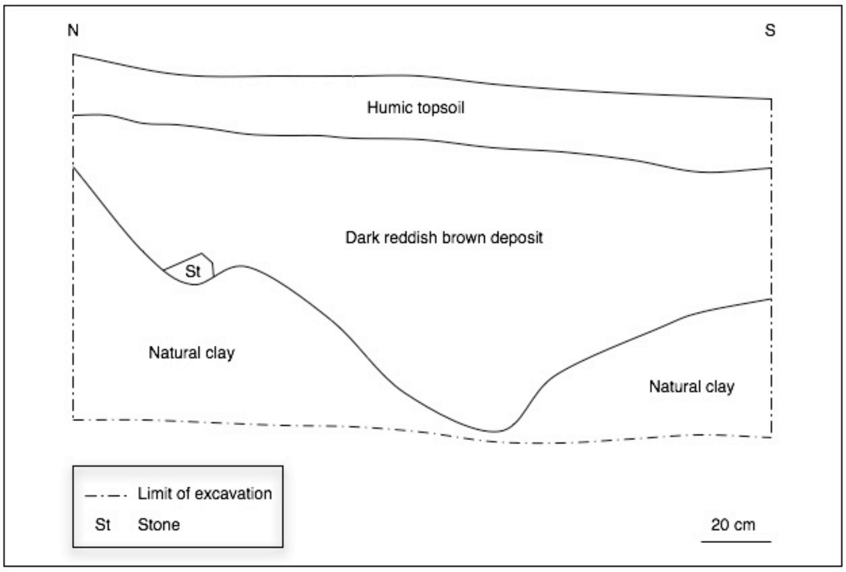


Figure 5.34 Mirongo Testpit A, west facing section

The second testpit (in the compound to the northeast of the other excavations) revealed a shallow linear feature, probably a small drainage ditch, plus a single, large slag block (which was sampled, Tr3S1M), a large number of slag fragments, broken pieces of tuyère, and a number of domestic pottery sherds, some with knotted-strip roulette decoration. A second potsherd from this testpit was also taken for analysis (Trench 3 Pot).

The final major undertaking at this site was the sampling of slag blocks for analysis. There were three distinct clusters of slag in the vicinity of the furnaces. The first (marked on Figure 5.29) comprised only six complete slag blocks amongst many comparatively large slag fragments. Roughly twenty metres to the east were two further clusters. Cluster 2 was comprised of approximately forty slag blocks, most of which had been broken, though generally remaining indicative of their original shapes and dimensions. Cluster 3 was a pile of buried slag blocks that had been cleared from a cassava field (Figure 5.35). Slag blocks from both of these clusters appeared on average to be significantly smaller than the slag blocks from either the furnace or Cluster 1, and many also displayed a peculiar concave shape in profile (*cf.* Figure 5.46). Several also had clear banana-stem impressions visible on the surface, in contrast to the reed impressions on the slag from the other clusters.

Figure 5.35 Slag blocks being uncovered at Cluster 3, Mirongo

ANALYTICAL RESULTS AND INTERPRETATION

TECHNICAL CERAMIC ANALYSES

Tuyère fragments were recovered from the excavated furnace and the two testpits at Mirongo. Macroscopic descriptions and dimensions were recorded of all excavated tuyère samples (*cf.* Appendix G), and there appeared on initial inspection to be two distinct styles of tuyère within the assemblage: thicker, darker tuyère fragments contrasting with thinner, reddish examples (Figure 5.36).

Bulk chemical analyses (PED-XRF) were carried out on two tuyère samples that had been excavated from the furnace, one from each of these macroscopic groups. A sample of the furnace wall lining was also analysed. Both of the tuyère samples were also analysed using reflected light microscopy, and one was analysed using SEM-EDS analysis.

Figure 5.36 Examples of tuyère fragments excavated from Mirongo, context (048), illustrating the two macroscopic groups

In addition, two samples of undecorated domestic pottery were analysed using PED-XRF: one from a coarse red ware that had been excavated from the pit feature in Testpit A, the other from a thin black ware, excavated from Testpit B (Figures 5.37 and 5.38).

Figure 5.37 Pottery, Testpit A, Mirongo

Figure 5.38 Pottery, Testpit B, Mirongo

The tuyère fragments recovered from the Mirongo excavations ranged in colour from light orange to mid brown and dark grey. The average internal diameter of these tuyères was 4.9cm (though the range covered 3cm in diameter through to 7cm), and several fragments appeared to suggest that the complete tuyères would have flared out towards one end. Unfortunately, there were no fragments that were particularly complete. The average thickness of the walls of the tuyères was 1.2cm (*cf.* Appendix G). Frequent large quartz grains and grog inclusions were visible on an initial inspection of the tuyères, which was later confirmed by the optical microscopy (Figures 5.39 and 5.40).

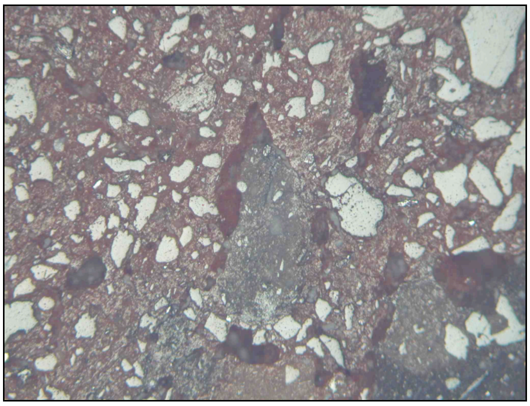


Figure 5.39 Grog and quartz inclusions, Tuyère A, Mirongo. Image width ≈ 2mm; PPL

It is possible that crushed quartz was added intentionally to the clay for the tuyères, as such a high occurrence of quartz is notably absent from the domestic pottery sample (Figure 5.41). These quartz grains generally ranged in size from 0.1 to 0.5mm, comprising an estimated 30-35% of the sample areas, and they would have improved the stability and temperature resistance of the clay by reducing the likelihood of fatal cracking. Occasional small, very bright inclusions were also noted in all of the pottery and tuyère samples, some of which were identified by SEM-EDS analysis to be zircon, whereas other infrequent inclusions consisted of alumina (approx. 20wt%), silica (20wt%), titania (40wt%) and iron oxide (20wt%).

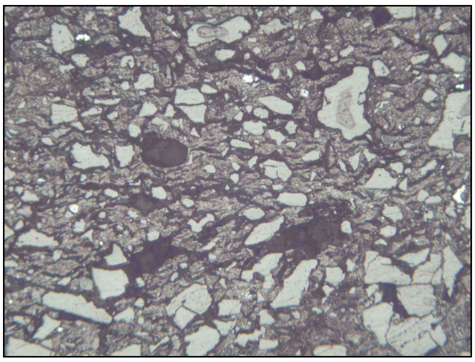


Figure 5.40 Quartz grains typical of tuyère samples (Tuyère B), Mirongo. Image width ≈ 2mm; PPL

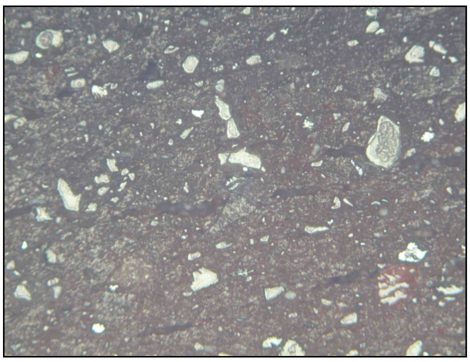


Figure 5.41 Quartz grains in sample of domestic pottery from (063), Mirongo. Image width ≈ 2mm; PPL

Again, the angular, elongated porosity visible in the tuyère samples is indicative of their method of manufacture, and the larger, sub-rounded voids visible in Figure 5.40 are the result of quartz grains falling off during sample preparation – an indication of the lack of bonding between the minerals and the sample matrix, which is a sign of the low firing and low vitrification of these ceramics.

The PED-XRF analyses, as shown below in Table 5.5 and as reported in full in Appendix H, demonstrate that the two different 'types' of tuyère initially identified are actually very similar in composition, suggesting that the macroscopic differences that were noted are likely to have derived from variable exposures to heat or reducing atmospheres. Both contain approximately 73wt% silica, and from 18wt% (Tuyère B) to 21wt% (Tuyère A) alumina. This gives a ratio of alumina to silica of roughly 1:3.5-4, in conjunction with a FeO content of about 4wt%. Refiring experiments on comparable technical ceramics by Freestone and Tite (1986: 41-46) suggest that such ceramics may have been capable of enduring temperatures of up to 1250°C, as were the technical ceramics from Kyakaturi. The only notable variations between the tuyères are in the levels of barium, lanthanum and cerium, but it is possible that this is due to slight variations in background geology at the clay source. Overall however, the two tuyère fragments show a remarkable consistency in composition.

MIRONGO	Major and minor compounds													
MIRONGO	Na_2O	MgO	Al_2O_3	*SiO_2*	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO
(MRG)	wt%	wt%	wt%	*wt%*	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
				original	adjusted									
Furnace Slag 1 B	≤0.26	0.18	5.61	*21.28*	17.67	2.29	0.13	1.28	1.90	0.40	0.06	0.09	2.87	62.75
Furnace Slag 1 M	≤0.19	0.11	4.75	*17.23*	13.78	1.92	0.24	0.86	1.21	0.35	0.06	0.11	3.10	69.05
Furnace Slag 1 T	≤0.15	0.16	5.44	*18.75*	15.19	2.16	0.26	0.94	1.35	0.38	0.06	0.09	3.04	66.34
Furnace Slag 2 M	0.25	0.30	5.70	*27.26*	25.08	2.40	0.14	1.16	2.71	0.45	0.04	0.06	2.95	55.54
Cluster 1 Slag 1 M	0.22	0.21	5.76	*30.03*	29.13	2.15	0.11	1.50	1.15	0.40	0.04	0.10	1.66	56.23
Cluster 1 Slag 3 M	/	0.13	5.51	*18.28*	14.62	1.72	0.31	1.24	1.05	0.36	0.08	0.28	0.82	69.81
Cluster 1 Slag 5 M	≤0.14	/	6.43	*19.73*	16.18	1.71	0.23	1.23	1.25	0.41	0.03	0.12	3.67	64.14
Cluster 1 Slag 6 B	0.30	0.30	6.80	*29.80*	28.91	1.90	0.12	1.28	1.44	0.53	0.04	0.08	1.68	55.20
Cluster 2 Slag 1 M	0.23	1.49	7.32	*32.66*	32.66	2.08	0.23	2.38	3.81	/	0.04	0.08	12.29	35.79
Cluster 3 Slag 1 B	/	0.22	9.55	*30.33*	29.42	0.93	0.09	0.92	1.63	/	/	0.13	11.85	42.69
Cluster 3 Slag 2 M	0.22	1.90	7.17	*34.84*	34.84	1.82	0.19	2.14	5.48	/	≤0.01	0.07	9.63	35.05
Cluster 3 Slag 4 B	0.16	0.49	7.53	*29.77*	28.87	1.06	0.07	1.78	2.38	/	/	0.06	12.17	39.99
Cluster 3 Slag 5 M	0.17	0.65	10.61	*26.98*	24.82	0.89	0.07	1.19	1.94	/	≤0.03	0.20	11.59	42.48
Trench 3 Slag 1 M	0.17	0.48	7.64	*31.82*	31.82	0.86	0.14	1.17	1.75	/	0.07	0.07	7.93	46.47
Furnace Wall	0.32	0.11	29.62	*46.97*	46.97	0.26	0.06	0.31	0.17	1.78	0.05	0.03	0.25	19.82
Tuyère A	0.37	0.31	20.68	*71.98*	71.98	0.02	0.04	0.69	0.23	1.44	0.01	0.02	0.02	4.02
Tuyère B	≤0.35	0.20	18.47	*74.56*	74.56	/	0.03	0.60	0.14	1.47	0.01	0.02	0.03	4.10
Test Pit A Pot	≤0.25	0.13	21.76	*67.87*	67.87	0.04	0.13	0.30	0.55	3.17	0.03	0.03	0.07	5.57
Test Pit B Pot	≤0.24	0.61	25.15	61.89	61.89	0.09	0.07	1.32	1.01	1.83	0.04	0.08	0.05	7.53

MIRONGO	Trace compounds											
MIRONGO	Co_3O_4	NiO	CuO	ZnO	Rb_2O	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
(MRG)	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Furnace Slag 1 B	277	/	263	/	/	547	73	1468	3288	1923	1184	842	101.81
Furnace Slag 1 M	449	/	384	/	/	427	54	1297	3683	1130	746	625	100.49
Furnace Slag 1 T	360	/	318	/	/	477	62	1390	3744	1361	918	704	102.14
Furnace Slag 2 M	339	/	264	/	/	637	75	1333	4105	1765	1033	864	105.73
Cluster 1 Slag 1 M	453	/	175	/	/	274	55	632	1449	554	543	253	104.91
Cluster 1 Slag 3 M	1096	/	629	/	/	207	51	617	537	430	534	≤142	105.83
Cluster 1 Slag 5 M	987	177	889	/	/	365	63	1039	3452	949	731	783	103.84
Cluster 1 Slag 6 B	443	/	198	/	/	373	95	778	1417	745	656	419	103.30
Cluster 2 Slag 1 M	/	≤15	177	/	/	1059	81	564	10152	1607	1032	1357	108.43
Cluster 3 Slag 1 B	/	32	120	/	/	326	71	445	14047	372	332	840	104.09
Cluster 3 Slag 2 M	/	17	314	/	/	1077	72	472	9457	1185	898	1080	107.95
Cluster 3 Slag 4 B	/	≤12	62	/	/	249	107	343	36073	2286	1874	4355	104.30
Cluster 3 Slag 5 M	/	18	99	/	/	189	91	274	27094	1264	921	2305	105.33
Trench 3 Slag 1 M	/	15	597	/	/	451	56	360	10703	482	706	882	107.00
Furnace Wall	353	64	189	91	39	41	/	640	215	289	347	154	83.55
Tuyère A	56	46	121	75	43	35	/	582	452	56	85	100	95.34
Tuyère B	63	42	137	74	31	19	/	577	201	116	145	112	102.17
Test Pit A Pot	115	50	83	84	13	36	/	1039	285	72	115	≤74	94.96
Test Pit B Pot	125	117	84	74	122	82	/	574	1255	30	≤67	101	91.11

Table 5.5 PED-XRF compositional data for all samples from Mirongo, normalised to 100%. All values are the average of the three analyses of each sample reported in Appendix H. 'Analytical total' shows the analytical total prior to normalisation

Figure 5.42 demonstrates visually how little variation is present in the major compositional compounds between the two samples, in comparison with the domestic pottery samples. The difference in silica levels between the tuyères and the domestic pottery is clearly apparent, and can be explained by the far greater number of quartz inclusions in the tuyère samples that were visible in the optical microscopy. Again, the furnace wall sample appears to have either been contaminated by the iron-rich charge or tempered with slag, as there is an unusually high iron oxide reading. An examination of crushed furnace wall suggests that it is the latter in this case.

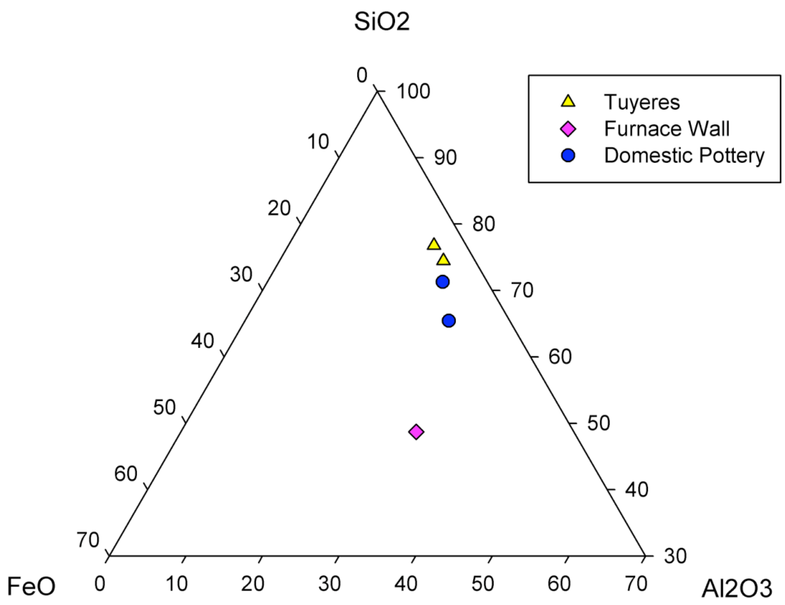


Figure 5.42 Truncated ternary diagram showing the chemical composition of tuyères, furnace wall and domestic pottery samples from Mirongo. Calculated from PED-XRF data, normalised to 100%

The domestic pottery samples show a much higher level of variation in all compounds than the tuyères do. Levels of soda, silica, titania and zirconia are slightly higher in the pottery from (056), whereas magnesia, potash, and iron, cobalt, and barium oxides appear higher in the pottery from (063). The variation in minor compounds is likely to be related to background geology. These variations are visually represented in Figures 5.43 and 5.44 below, which also clearly show that although the compositions of the two tuyère fragments match each other very closely, the two pottery sherds are both very different from each other, as well as being significantly different compositionally from the tuyère fragments.

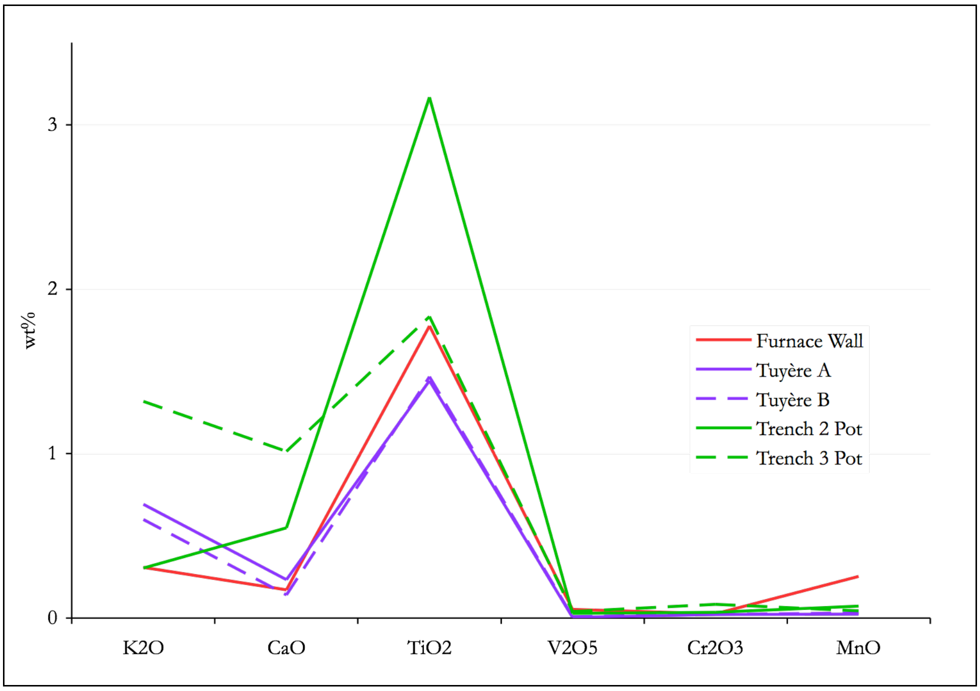


Figure 5.43 Line plot showing major and minor compounds (less Al_2O_3, SiO_2, FeO) of all analysed ceramics from Mirongo, calculated from PED-XRF data normalised to 100%

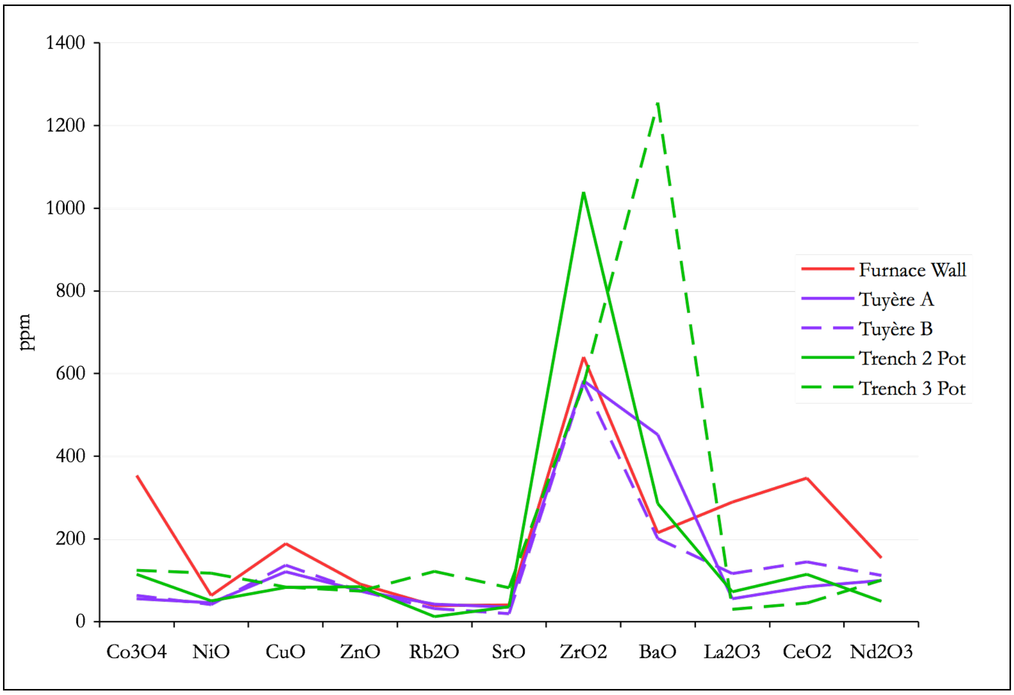


Figure 5.44 Line plot showing trace compounds of all analysed ceramics from Mirongo, calculated from PED-XRF data normalised to 100%

Due to the fact that there is a large proportion of quartz in the tuyère samples, it is likely that the PED-XRF bulk data will show a misleadingly low alumina to silica ratio, making the refractory quality of the ceramic appear lower than it actually is. In addition, large cracks are visible within the samples and these could potentially contain contaminants such as soil, which may also distort the PED-XRF data. As such, SEM-EDS analysis of the matrix at high magnification was undertaken on one of the tuyère samples in order to gain a more accurate understanding of the refractory qualities of the clay, and the results of this are shown in Table 5.6.

MIRONGO	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V_2O_5	FeO	(wt%)
Tuyère B	0.2	0.4	33.9	55.7	0.5	0.6	0.3	1.4	0.1	7.0	

Table 5.6 Averaged SEM-EDS compositional data for tuyère sample B, Mirongo normalised to 100%

These results are markedly different from the PED-XRF data presented in Table 5.5, notably in the values of alumina, which now appear to be significantly higher. However, the proportion of alumina to silica is now more in keeping with the raised alumina levels of the furnace wall sample, suggesting a naturally high level of alumina in the clay being utilised, which is likely to be related to a kaolinitic clay source.

To summarise, the tuyères analysed from the furnace at Mirongo were made from highly refractory clays, with quartz and grog inclusions added during manufacture to improve stability and increase their resistance to the prolonged high temperatures they were intended to endure. The close compositional data, and very similar optical microscopy results for the two tuyère samples suggest that there may have been an element of control over the use of certain clays and tempering materials and their preparation for these technical ceramics. By comparing this to the two sherds of the domestic pottery that were analysed, it is possible that a less systematic selection strategy was carried out for these materials along with a different tempering strategy (no grog), with their very different technical requirements, although with such a limited number of samples such inferences are merely speculative at this stage.

METALLURGICAL ANALYSES

MACRO-DESCRIPTIONS

As previously described, three clusters of slag blocks and slag fragments were recorded at Mirongo, and slag was also obtained from the excavated furnace and the two testpits. Macroscopic descriptions and dimensions were recorded of all of the slag blocks and some of the larger slag fragments from these areas. Bulk chemical analyses (PED-XRF) were carried out on twelve slag blocks (*cf.* Table 5.7). Three samples were analysed from one of the slag blocks from the furnace, one from the bottom, middle and top of the slag block.

All slag collected as part of this study appeared from a basic visual inspection to be furnace slag resulting from iron smelting activity. All the slag blocks and fragments ranged in colour from dark grey to a lighter grey with orange and blue aspects, and they varied considerably in their size and weight, ranging up to a maximum of approximately 36kg (Table 5.7).

		Complete	Width a	Width b	Depth	Weight	Samples				
Cluster	Slag #	block?	cms	cms	cms	kg	Top	Middle	Bottom	ED-XRF	OM/SEM-EDS
1	1	Y	24	23	15	8			✔	✔	
	2	Y	23	19	17	9					
	3	N	30	42	22	30.5	✔	✔	✔	✔	✔
	4	N	36	22	12	12					
	5	Y	56	32	24	35	✔	✔	✔	✔	
	6	N	28	28	16	23	✔	✔	✔	✔	✔
2	1	N	29	17	7	9		✔		✔	
	2	N	25	15	18	7		✔			
	3	N	17	17	9	4.5		✔			
3	1	Y	30	20	21	12	✔		✔	✔	
	2	N	33	25	5	14	✔	✔	✔	✔	✔
	3	Y	47	25	25	32					
	4	N	23	14	12	7.5	✔		✔	✔	✔
	5	Y	26	26	13	14	✔	✔	✔	✔	
	6	N	25	25	27	20	✔		✔		
	7	Y	26	23	23	12.5					
	8	N	26	19	15	11.5					
	9	Y	20	15	13	7					
Furnace	1	Y	23	38	20	11	✔	✔	✔	✔	✔
	2	Y	33	44	30	36	✔	✔	✔	✔	
Trench 3	1	N	37	38	19	15	✔	✔	✔	✔	✔

Table 5.7 Summary of macroscopic information recorded for the slag blocks from Mirongo

Density also varied throughout the sample set. There were few pieces of slag that displayed clear flow structures and those that did tended to be smaller slag fragments. This phenomenon was probably the result of drips solidifying inside the furnace rather than the result of slag being tapped from the furnace. Generally, the morphology of the samples indicated that all the slags had formed inside a furnace, and were not tapped. Many of the samples have plant impressions on the surface, indicating that the furnace bowl or base was probably packed with grasses or reeds to support the furnace charge (Figure 5.45). Many of the slag samples also have medium to large (approximately $2cm^3$) charcoal fragments, or their impressions, embedded in them.

Figure 5.45 Example of impressions of reeds or grasses (some highlighted in red circles) preserved in Slag 1, Cluster 3, Mirongo. Image width: approximately 10cm

A number of the slag blocks are near circular in plan with a flattened lower surface showing plant impressions, and are plano-convex in profile (Figures 5.46 and 5.47). These are suggestive of being formed in a relatively shallow bowl furnace, and were not reminiscent of the shape of the furnace base excavated at this site. They measured approximately 30cm in diameter, and were only apparent in Clusters 2 and 3. Two examples of these were analysed: Cluster 2, Slag 1 and Cluster 3, Slag 2.

Figure 5.46 Profile of Slag 2, Cluster 3

Figure 5.47 Base of Slag 2, Cluster 3

All other slag blocks and fragments appeared to be more irregular in shape, and were suggestive of being formed within a deep pit furnace, often with areas where the slag had cooled against the wall of the furnace, and with many porous areas where the slag had formed around the packing material of grasses and reeds. In Clusters 2 and 3, in addition to impressions of small reeds and grasses, there were also intermittent examples of banana pseudostem impressions (Figure 5.48). These were notably absent from Cluster 1 and the slag from the furnace, where the dominant plant materials used were large grasses and reeds. The use of bananas within iron smelting episodes has been identified in other parts of Uganda (see Iles 2009b, forthcoming), and will be discussed in greater detail in Chapter 7.

Figure 5.48 Banana pseudostem impression on surface of Slag 2, Cluster 2, Mirongo

ANALYSIS

The PED-XRF results, presented in Table 5.5 and reported in full in Appendix H, show that all the slags that were analysed are composed primarily of iron oxide and silica, which is characteristic of bloomery slag. They generally fall within the 'normal' range of values for these compounds, defined by Pleiner (2000: 252) as 40-70wt% FeO and 15-40wt% SiO_2, with a number of outliers, such as Slags 3 and 5 of Cluster 1, and Slag 1 from the furnace, which all have relatively low silica levels (and correspondingly high iron oxide levels), and Slag 1 from Cluster 2, and Slag 2 from Cluster 3 (the plano-convex examples), which both have low iron oxide levels. The ratio of alumina to silica ranges between roughly 1:2 and 1:5 in all of the samples, which is a fairly typical range.

The concentrations of alumina, soda, magnesia, lime, manganese oxide and potash fall generally within the expected ranges of results for these compounds, with a few notable exceptions in the alumina and lime readings. Like the slag at Kyakaturi (*cf.* this chapter, Part One), levels of phosphate tend to be slightly higher than might be expected (Pleiner 2000: 252). In terms of trace compounds, high levels of cobalt, copper, strontium, zirconium and barium oxides are apparent in many of the samples, and titania is present, albeit in relatively small quantities, in some samples, though below detection limits in others. The coefficients of variation for all compounds across the sample set were very high, with none falling below 20% (Figure 5.49).

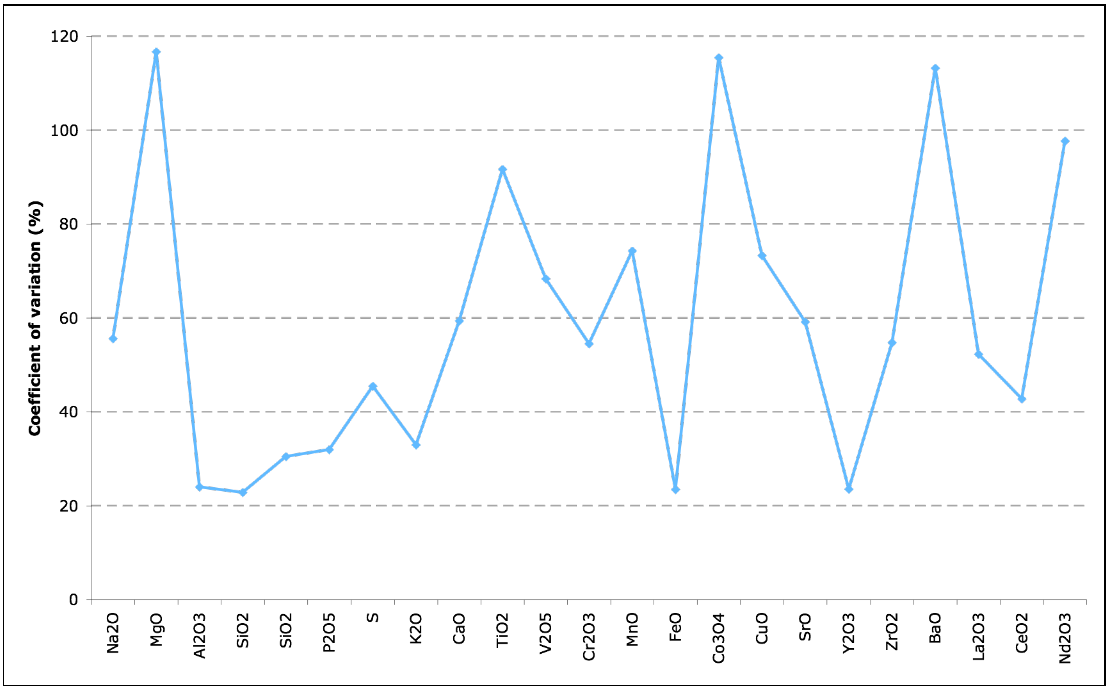


Figure 5.49 Coefficients of variation for all compounds in the sampled slag blocks from Mirongo (less NiO, which has a CV of 234%), calculated from PED-XRF data normalised to 100%

In order to assess the internal homogeneity or heterogeneity of the slag blocks, the three samples taken from the top, middle and bottom of Slag 1 from the furnace were also considered separately. Figure 5.50 illustrates the amount of variation within the major, minor and trace compounds of the single slag block.

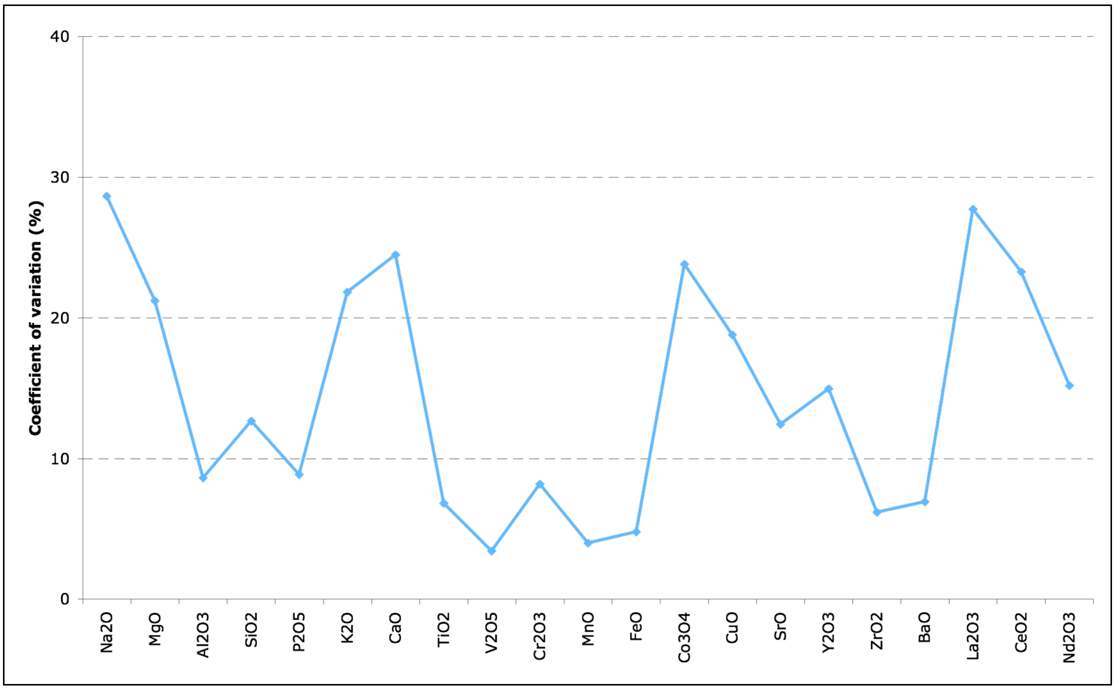
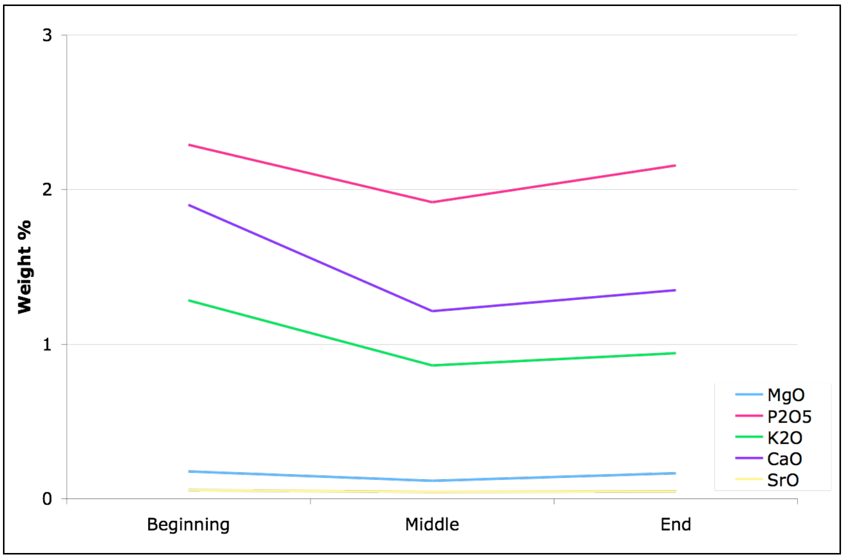


Figure 5.50 Coefficient of variation for all compounds through start-middle-end of smelt, calculated from three samples from Furnace Slag 1, Mirongo

The major compounds of the slag – silica, alumina and iron oxide – appear to vary relatively little throughout the course of the smelt, with coefficients of variation remaining lower than 15%. Concentrations of magnesia, potash and lime are more variable, as are the trace compounds, although this is to be expected given their low concentrations. The contribution made to the smelt by the compounds related to the fuel ash – lime, potash, phosphate, magnesia and strontium oxide – appear to be higher in the earlier and later stages of the smelt (Figure 5.51). Other compounds, namely alumina, silica and titania, also show a pronounced 'dip', during the middle part of the smelt, and this contrasts with the higher iron oxide levels at this time.

The higher fuel ash contributions at the start of the smelt could illustrate a preliminary firing (or preheating) of the furnace prior to the ore charge being added (as has already been suggested in the large crystal sizes – and therefore slow solidification time – of most of the slag samples), or, alternatively, the lining of the furnace bowl with ash, as has been recorded in this area ethnographically (Childs 1998a: 131). As at Kyakaturi, it appears that towards the middle of the smelt the efficiency then declined, rising again towards the end of the smelt, when the fuel ash contribution also rose again slightly. The lowered levels of alumina and silica at this time also indicate that the furnace may have decreased slightly in temperature at this time, thus meaning that less of the lining and/or technical ceramics would have melted into the smelt.



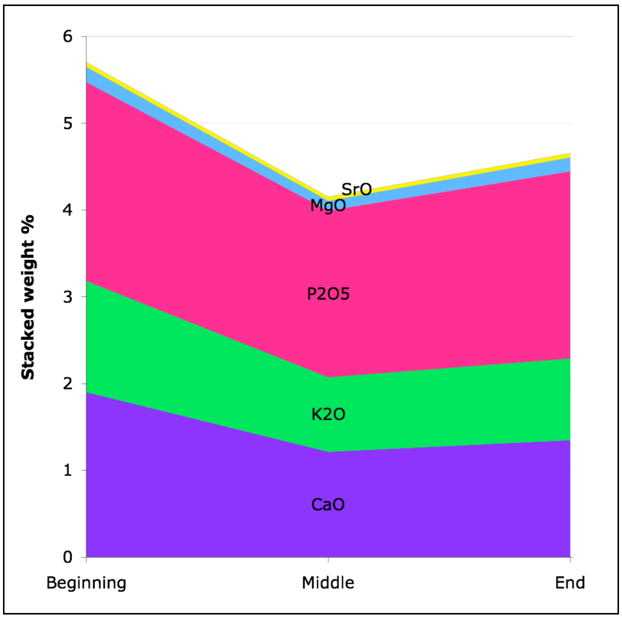


Figure 5.51 Fuel ash contributions through course of smelt represented by Furnace Slag 1, Mirongo, showing original normalised PED-XRF values (top) alongside the accumulative contribution (bottom), calculated from the same values

On closer examination of the PED-XRF data, there were revealed some subtleties of variation across the sample set. There appear to be two distinct compositional groups: that of Cluster 1 and the slags from the furnace (which I will from henceforth refer to as Group 1); and that of Clusters 2 and 3, and the slag from Trench 3 (Group 2). Referring back to the map of the site (Figure 5.29), it is also relevant to re-state that Cluster 1 and the furnace are spatially very close, as are Clusters 2 and 3, and that the slag from Group 2 also appear to be distinct from those from Group 1 in terms of slag morphology and the presence or absence of banana pseudostem impressions. These groupings will be discussed in more detail below.

When the coefficients of variation of these two groups were recalculated separately, much more reasonable values were generated (Table 5.8), except for nickel oxide, which has a single outlying value in Group 1.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	NiO	CuO	SrO	Y_2O_3	ZrO2	BaO	La_2O_3	CeO_2	Nd_2O_3
Group 1 CV	61	58	11	33	13	39	17	37	14	32	58	39	10	56	283	63	34	22	33	50	49	29	50
Group 2 CV	53	76	17	12	42	49	37	54	/	132	51	16	11	/	50	88	72	22	25	62	60	53	75
Combined CV	56	117	24	31	32	45	33	59	92	68	55	74	23	115	234	73	59	24	55	113	52	43	98

Table 5.8 Coefficients of variation for all compounds of all slag samples from Mirongo, with compositional groups considered both separately and together

GROUP 1

The samples from Group 1 have levels of titania ranging up to 0.5wt%, and cobalt oxide of up to 0.1wt%, whereas these compounds are below the detection limits in the samples from Group 2. Copper and zirconium levels are also significantly raised in Group 1, with measurements of up to 0.1wt% each – notably higher than the levels in Group 2. Phosphate levels are also higher in Group 1 (averaging 2wt% as compared to 1wt% in Group 2). As discussed in part one of this chapter, these levels might have had significant consequences for the attributes of the resultant iron. The iron oxide levels of the Group 1 samples are also markedly higher than those from Group 2 – ranging from 55 to 70wt%, with a mean value of 62wt%. Correspondingly, wüstite is a dominant feature in all but one of the Group 1 samples examined by optical microscopy.

The three samples from the furnace slag (FS1B, FS1M, FS1T) and the sample from Slag 3 of Cluster 1 (C1S3M) were very similar microscopically, as would be expected from the bulk chemical analyses. All showed a high abundance of wüstite, ranging from approximately 30area% in sample FS1B (which corresponds with the lowest iron oxide reading out of these four samples) to approximately 70area% in FSM and C1S3M, which both had the highest iron oxide readings.

The samples from the base (FS1B) and the top (FS1T) of the furnace slag were quite porous, with several areas of corrosion evident. Most interesting was the extent of pitting in the wüstite throughout all of these four samples (Figure 5.52). In order to assess what might have caused this pitting, the wüstite of sample C1S3M was examined under high magnification for evidence of texturing within it, and it appeared that in some cases there were small, darker patches within the wüstite. The SEM-EDS microanalyses revealed that in general the wüstite also contained traces of alumina, titania and manganese oxide, whereas the darker patches contained fewer of these impurities, being instead pure iron oxide, and this may have made those areas more prone to corrosion. The presence of this corrosion is worth noting as it will have primarily affected the glassy component of the slag, thereby potentially slightly skewing the bulk chemical results of these samples.

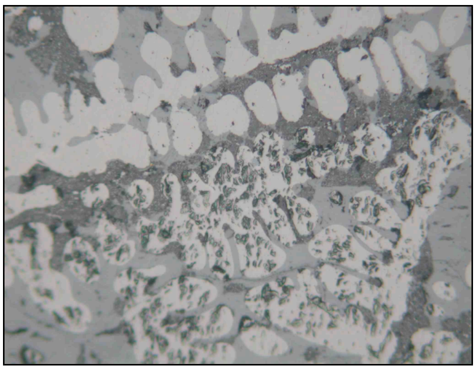


Figure 5.52 Photomicrograph of sample FS1M, Mirongo, showing heavily degraded dendritic wüstite contrasting with a non-degraded example. Image width ≈ 0.5mm; PPL

The blocky fayalite structure in all these four samples indicated a slow cooling rate for the slag throughout the smelt, which suggests that even at the beginning of the smelt the slag was not dripping down into a cold furnace pit, emphasising the possibility of the furnace being preheated. The SEM-EDS analysis showed the fayalite to be relatively pure Fe_2SiO_4, with minimal substitutions from other compounds. Occasional darker, euhedral crystals (Figure 5.53) were also present in the optical microscopy study, which were confirmed by micro-analysis to be hercynite ($FeO·Al_2O_3$), and occasional metallic iron droplets were present in all of the samples. The glassy matrix was shown to be approaching the composition of leucite ($K_2O·Al_2O_3·4SiO_2$), and had eutectic wüstite exsolving out of it (Figure 5.54).

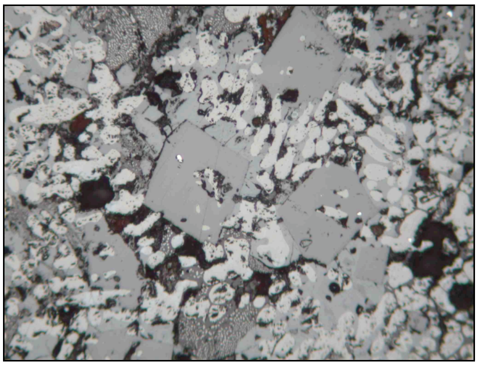


Figure 5.53 Sample FS1T, Mirongo, showing angular hercynite phases (dark grey), first generation wüstite (white) and fayalite (light grey). Image width ≈ 1mm; PPL

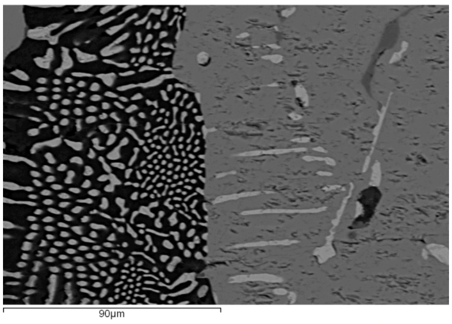


Figure 5.54 BSE image of sample C1S3M, Mirongo showing eutectic wüstite in a leucitic matrix

The other sample from Group 1 to be studied using optical microscopy was Slag 6 of Cluster 1 (C1S6M). This contrasted quite strongly with the samples previously described, as it was dominated by lathes of fayalite – comprising approximately 90area% – in a glassy matrix (Figures 5.55 and 5.56). No wüstite was present, which is reflective of the relatively low iron oxide readings for this sample in the bulk analysis. Small, pinkish phases were also present (approximately 2area%, Figure 5.56), likely ulvite spinels (Fe_2TiO_4), which may reflect the slightly higher titania levels in this slag. No microanalysis was carried out on this sample.

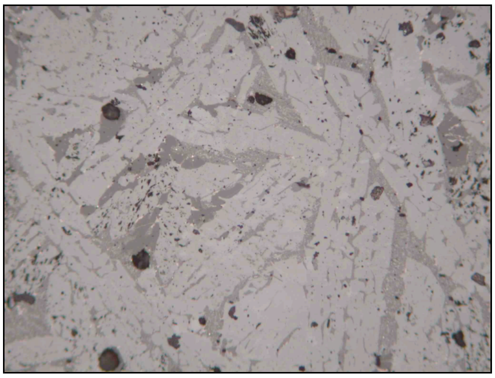


Figure 5.55 Photomicrograph showing lathes of fayalite in sample C1S6M, Mirongo. Image width ≈ 1mm; PPL

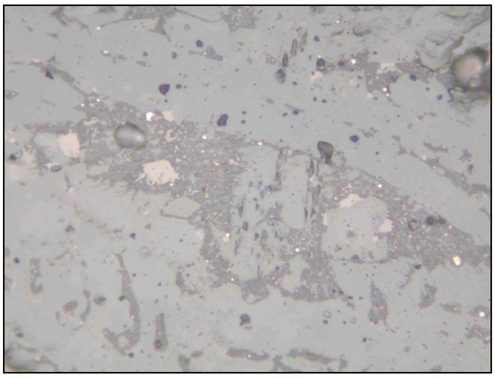


Figure 5.56 Photomicrograph showing small pink phases in the glassy matrix among light grey fayalite, C1S6M, Mirongo. Image width ≈ 0.2mm; PPL

GROUP 2

The Group 2 samples tended to have comparatively high levels of manganese oxide (which range up to 12wt% as compared to a maximum level of 4wt% in Group 1)[1], strontium oxide, and particularly high levels of barium oxide, of up to 3.6wt% compared to a maximum of 0.4wt% in Group 1. Levels of lime are particularly variable within this group. Contrasting with the samples from Group 1, the iron oxide levels of the Group 2 samples are particularly low, ranging from 35 to 46wt%, with a mean value of 40wt%. Levels of silica and alumina are correspondingly raised. This suggests that relatively few of the iron oxides that were in the ore have remained in the slag, as most of the iron oxides have been reduced to iron and have separated from

[1] Although actual manganese contents may well have been considerably higher (*cf.* Chapter 4). At 4wt%, the manganese content is likely to have been underestimated by perhaps 17-20%; at 12wt%, the extent of underestimation is not known but is likely to be somewhat more pronounced.

the slag successfully, and this, reinforced by the absence of uncombined iron (wüstite) in the microstructure (see below), is indicative of a fairly efficient process (Pleiner 2000: 253).

The two samples that were from slag blocks with a plano-convex shape, are, although largely similar in composition to the others from Group 2, slightly enriched with the fuel ash compounds of magnesia, phosphate, sulphur, potash, lime and strontium oxide, with correspondingly lower levels of iron oxides. Clearly, some technical parameters are different between these two groups, and overall, the slag from Group 2 would appear to be from the more chemically efficient process.

The three samples examined using optical microscopy from Group 2 – C3S2M, C3S4B, Tr3S1M – all appeared relatively similar. They were all dominated by blocky olivine phases, with occasional darker hercynite phases, and infrequent lighter phases (Figure 5.57), which SEM-EDS analysis found to be ulvite with high alumina and manganese oxide contents (of approximately 12wt% and 18wt% respectively). Very little wüstite is apparent in these samples, which is consistent with the low iron oxide levels in the bulk chemical analyses.

Microanalysis of the glassy matrix again showed that it was leucitic, but also highlighted the particularly high levels of manganese oxide in the olivines, which reached as high as 38wt%. This meant that it could not be termed fayalite as such, but was more correctly knebelite: $(Fe,Mn)_2SiO_4$. Although lime readings in the knebelite were generally around 2wt%, there were two readings that were much higher: 5wt% and 13wt%. These compounds act as a substitution for iron oxide in the formation of olivines, freeing up more iron oxide to reduce to iron metal and making the smelt overall more efficient in terms of making available a higher proportion of the iron that is present in the ore.

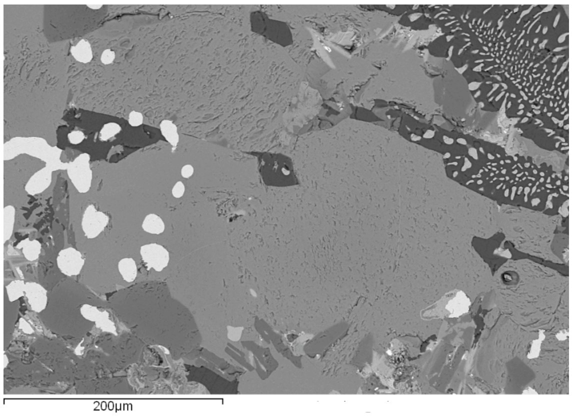


Figure 5.57 BSE overview image of sample from Slag 6, Cluster 3, Mirongo. Visible are fayalite phases (mid grey); first generation wüstite (light grey); hercynite (dark grey) and dark glassy matrix with eutectic wüstite

Metallic iron is also present in all of the samples, generally as small droplets, although it sometimes occurs as foils or retaining the shape of the wüstite dendrites from which it derived. In some samples, the iron forms distinct lines crossing the sample (see Figure 5.58). This is possibly due to the continuing exposure of the outer layers of the slag to a reducing atmosphere, even after it has fallen into the slag pit. This would have resulted in the reduction of wüstite to iron in a film covering the upper surface of the slag. As more slag fell into the pit, this film of reduced iron would remain as a line in the interior of the slag (*cf.* also Iles and Martinón-Torres 2009).

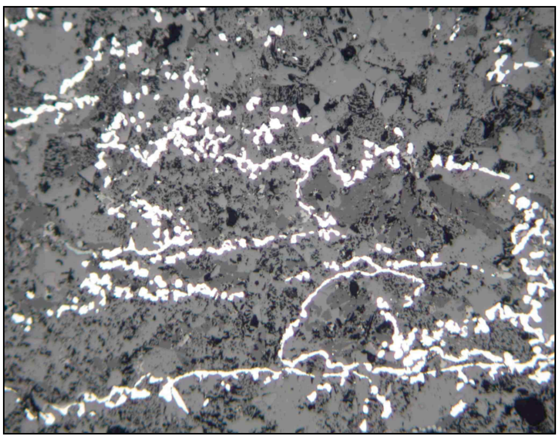


Figure 5.58 Photomicrograph showing some of the lines of iron metal that criss-cross the sample from C3S2M, Mirongo. Image width ≈ 2mm; PPL

DISCUSSION AND SUMMARY

The existence of the two broad compositional slag groups at Mirongo is very interesting. The disparity in the manganese oxide levels between the two groups is of particular note. As has been briefly mentioned, this is likely to be linked to the low iron oxide levels seen in the slag samples from Group 2. In addition to the manganese acting to replace the iron in the olivines, the occurrence of manganese oxide in the ore would also result in a very fluid slag that would easily separate from the gangue by lowering the melting point of the slag (*cf.* Charlton 2007; see also Chapter 7 where manganese is discussed in detail). Together these factors would significantly increase the potential output of a smelt. The tendency towards slightly raised levels of lime in the samples from Group 2 would also contribute to this effect by acting in a similar way.

In order to investigate the relationships between these various compounds and therefore between the two compositional groups, principal component analysis was undertaken (*cf.* Appendix I). Unsurprisingly, when factor analysis was applied to all samples from the site, Groups 1 and 2 were prominently separated along one major axis – Principal Component 1 (PC1) – reflecting the major compositional differences as outlined above (Figures 5.59 and 5.60).

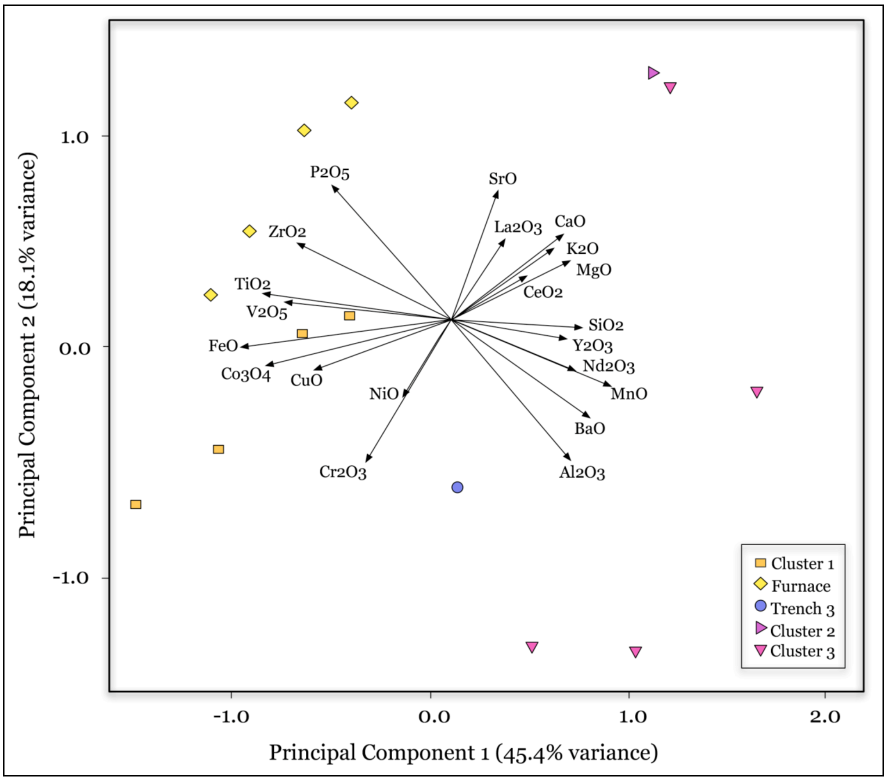


Figure 5.59 Graph of Mirongo slag samples in principal component space (PC1 vs. PC2)

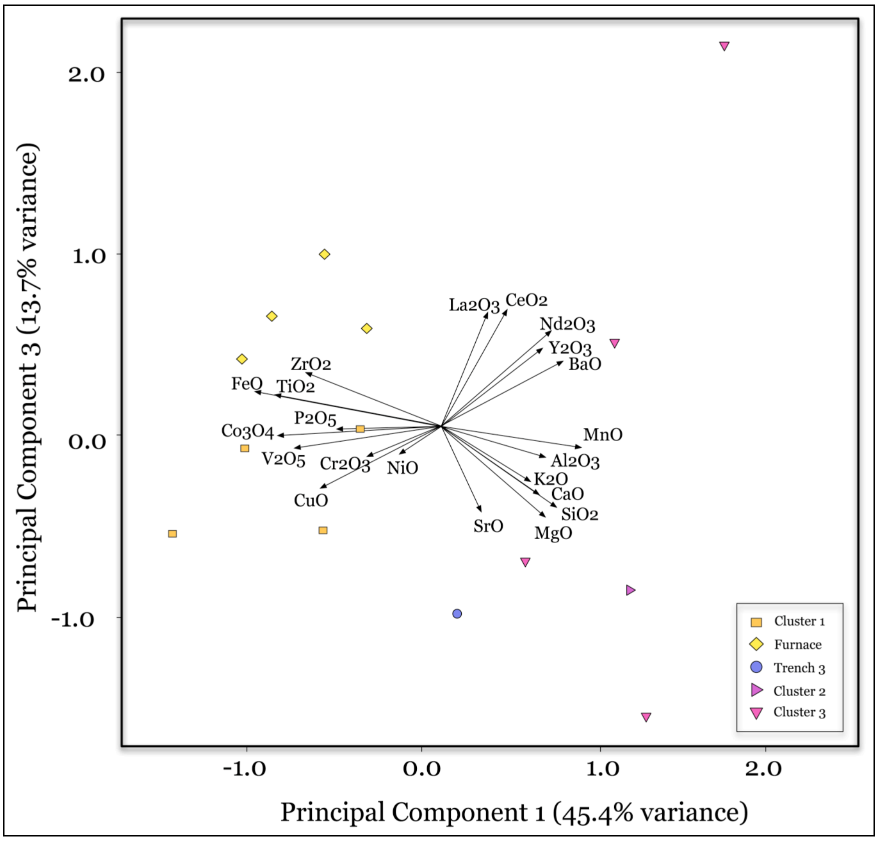


Figure 5.60 Graph of Mirongo slag samples in principal component space (PC1 vs. PC3)

However, in order to understand the internal structuring of these two compositional groups, principal component analysis was then undertaken on each group separately. In doing so, it was possible to look more into the relationship between manganese oxide and the other compounds to try and explain why there were such high levels occurring in the Group 2 samples (see Figures 5.61 and 5.62, and Appendix I).

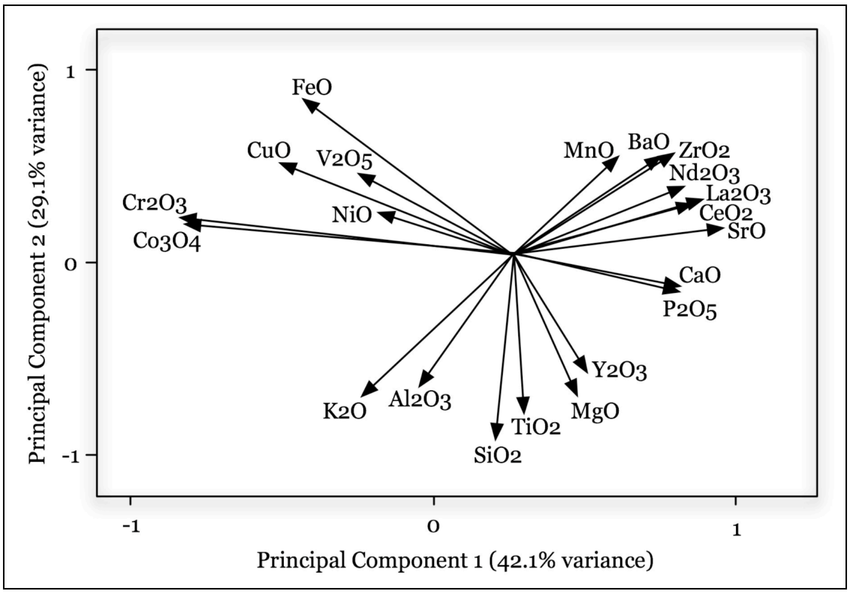


Figure 5.61 Loading vectors from principal component analysis, Group 1, Mirongo (PC1 vs. PC2)

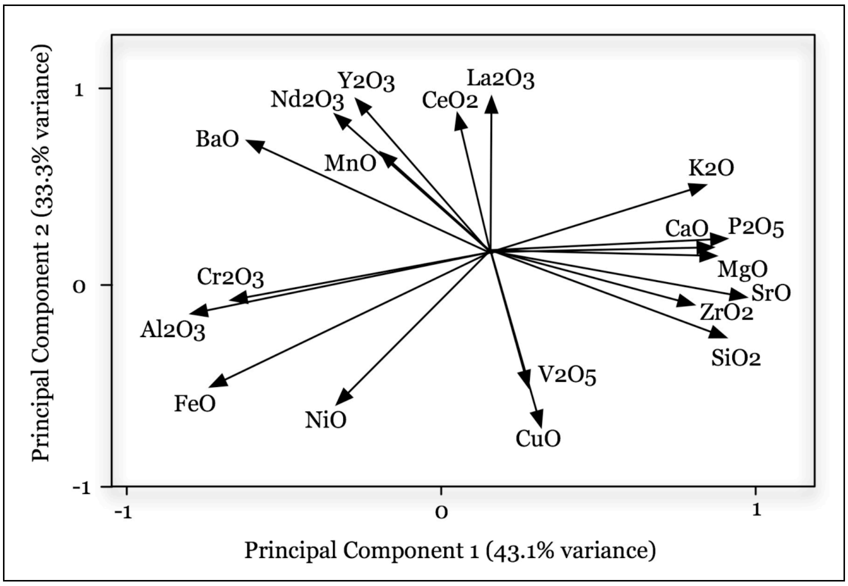


Figure 5.62 Loading vectors from principal component analysis, Group 2, Mirongo (PC1 vs. PC2)

Through an examination of the above graphs in conjunction with the correlation matrices below (Tables 5.9 and 5.10), it was possible to begin to discuss the significance of the manganese oxide and the other 'ingredients' that might have been used in the smelts. The compounds presented in the correlation matrices have been arranged in a sequence that groups them according to their strongest correlations, which is likely to reflect the principal source from which these compounds are likely to have derived (i.e. ceramic, fuel ash, etc.), and colour coded in terms of the strength and direction of the correlations, in order to aid in the interpretation of this data. Unfortunately, there were no fragments of unreduced ore excavated from the furnace that could be analysed, which may have assisted in the interpretation of the data.

	Al_2O_3	SiO_2	MgO	K_2O	TiO_2	Y_2O_3	FeO	CuO	Co_3O_4	Cr_2O_3	NiO	V_2O_5	P_2O_5	CaO	SrO	MnO	BaO	ZrO_2	La_2O_3	CeO_2	Nd_2O_3	
Al_2O_3		0.6	0.2	0.6	0.8	0.7	-0.6	0.1	0.2	-0.1	0.4	-0.7	-0.2	0.0	-0.1	-0.1	-0.3	-0.4	-0.2	-0.2	0.0	Al_2O_3
SiO_2	0.6		0.7	0.7	0.8	0.6	-1.0	-0.6	-0.4	-0.5	-0.2	-0.6	0.4	0.3	0.0	-0.3	-0.3	-0.4	-0.2	-0.2	-0.2	SiO_2
MgO	0.2	0.7		0.2	0.7	0.6	-0.7	-0.8	-0.6	-0.4	-0.7	-0.1	0.6	0.6	0.4	-0.3	-0.1	0.0	0.2	0.2	0.0	MgO
K_2O	0.6	0.7	0.2		0.4	0.2	-0.6	-0.1	0.1	0.1	0.1	-0.4	0.0	0.0	-0.4	-0.5	-0.6	-0.6	-0.3	-0.3	-0.4	K_2O
TiO_2	0.8	0.8	0.7	0.4		0.9	-0.8	-0.3	-0.2	-0.4	0.0	-0.6	0.1	0.4	0.2	-0.1	-0.2	-0.2	0.0	0.0	0.1	TiO_2
Y_2O_3	0.7	0.6	0.6	0.2	0.9		-0.7	-0.4	-0.4	-0.5	-0.1	-0.4	0.2	0.5	0.4	0.1	0.1	0.1	0.3	0.3	0.3	Y_2O_3
FeO	-0.6	-1.0	-0.7	-0.6	-0.8	-0.7		0.6	0.5	0.6	0.1	0.7	-0.5	-0.5	-0.3	0.1	0.1	0.2	-0.1	-0.1	-0.1	FeO
CuO	0.1	-0.6	-0.8	-0.1	-0.3	-0.4	0.6		0.9	0.6	0.8	0.0	-0.7	-0.4	-0.4	0.2	0.0	-0.1	-0.3	-0.3	0.0	CuO
Co_3O_4	0.2	-0.4	-0.6	0.1	-0.2	-0.4	0.5	0.9		0.8	0.6	0.1	-0.8	-0.5	-0.7	-0.3	-0.5	-0.6	-0.6	-0.6	-0.5	Co_3O_4
Cr_2O_3	-0.1	-0.5	-0.4	0.1	-0.4	-0.5	0.6	0.6	0.8		0.0	0.6	-0.7	-0.5	-0.7	-0.6	-0.6	-0.5	-0.6	-0.5	-0.7	Cr_2O_3
NiO	0.4	-0.2	-0.7	0.1	0.0	-0.1	0.1	0.8	0.6	0.0		-0.6	-0.5	-0.2	-0.1	0.5	0.2	0.0	-0.1	-0.1	0.3	NiO
V_2O_5	-0.7	-0.6	-0.1	-0.4	-0.6	-0.4	0.7	0.0	0.1	0.6	-0.6		-0.1	-0.2	-0.1	-0.4	-0.2	0.1	0.0	0.1	-0.3	V_2O_5
P_2O_5	-0.2	0.4	0.6	0.0	0.1	0.2	-0.5	-0.7	-0.8	-0.7	-0.5	-0.1		0.8	0.8	0.2	0.5	0.6	0.7	0.7	0.5	P_2O_5
CaO	0.0	0.3	0.6	0.0	0.4	0.5	-0.5	-0.4	-0.5	-0.5	-0.2	-0.2	0.8		0.9	0.3	0.5	0.6	0.8	0.7	0.6	CaO
SrO	-0.1	0.0	0.4	-0.4	0.2	0.4	-0.3	-0.4	-0.7	-0.7	-0.1	-0.1	0.8	0.9		0.7	0.8	0.9	1.0	0.9	0.9	SrO
MnO	-0.1	-0.3	-0.3	-0.5	-0.1	0.1	0.1	0.2	-0.3	-0.6	0.5	-0.4	0.2	0.3	0.7		0.9	0.8	0.7	0.6	0.9	MnO
BaO	-0.3	-0.3	-0.1	-0.6	-0.2	0.1	0.1	0.0	-0.5	-0.6	0.2	-0.2	0.5	0.5	0.8	0.9		0.9	0.8	0.7	0.9	BaO
ZrO_2	-0.4	-0.4	0.0	-0.6	-0.2	0.1	0.2	-0.1	-0.6	-0.5	0.0	0.1	0.6	0.6	0.9	0.8	0.9		0.9	0.9	0.9	ZrO_2
La_2O_3	-0.2	-0.2	0.2	-0.3	0.0	0.3	-0.1	-0.3	-0.6	-0.6	-0.1	0.0	0.7	0.8	1.0	0.7	0.8	0.9		1.0	0.9	La_2O_3
CeO_2	-0.2	-0.2	0.2	-0.3	0.0	0.3	-0.1	-0.3	-0.6	-0.5	-0.1	0.1	0.7	0.7	0.9	0.6	0.7	0.9	1.0		0.9	CeO_2
Nd_2O_3	0.0	-0.2	0.0	-0.4	0.1	0.3	-0.1	0.0	-0.5	-0.7	0.3	-0.3	0.5	0.6	0.9	0.9	0.9	0.9	0.9	0.9		Nd_2O_3

Table 5.9 Correlation matrix generated using SPSS v.17.0 software, Group 1, Mirongo. In this and future correlation matrices, negative correlations equal to and stronger than -0.6 are highlighted in grey, positive correlations of 0.6 and 0.7 are highlighted in pale yellow and positive correlations of 0.8 to 1.0 are highlighted in bright yellow. Compounds may not be listed in the same order in this and subsequent matrices

	Al_2O_3	SiO_2	MgO	P_2O_5	K_2O	CaO	SrO	ZrO_2	FeO	CuO	Cr_2O_3	NiO	V_2O_5	MnO	Y_2O_3	BaO	La_2O_3	CeO_2	Nd_2O_3	
Al_2O_3		-0.8	-0.5	-0.6	-0.7	-0.6	-0.7	-0.5	0.5	-0.4	1.0	0.6	-0.3	0.3	0.1	0.3	-0.3	-0.4	0.0	Al_2O_3
SiO_2	-0.8		0.7	0.7	0.6	0.7	0.9	0.8	-0.5	0.5	-0.8	-0.1	0.3	-0.4	-0.5	-0.7	-0.1	-0.1	-0.5	SiO_2
MgO	-0.5	0.7		0.9	0.8	1.0	0.9	0.6	-0.9	0.1	-0.3	-0.3	0.0	-0.1	-0.1	-0.5	0.3	0.1	-0.2	MgO
P_2O_5	-0.6	0.7	0.9		0.9	0.9	0.9	0.8	-0.9	0.0	-0.4	-0.4	0.1	0.2	0.0	-0.5	0.3	0.1	-0.2	P_2O_5
K_2O	-0.7	0.6	0.8	0.9		0.8	0.8	0.6	-0.9	-0.1	-0.6	-0.7	0.0	0.2	0.3	-0.2	0.6	0.5	0.1	K_2O
CaO	-0.6	0.7	1.0	0.9	0.8		0.9	0.6	-0.9	0.1	-0.4	-0.3	-0.1	-0.1	0.0	-0.4	0.3	0.1	-0.2	CaO
SrO	-0.7	0.9	0.9	0.9	0.8	0.9		0.8	-0.8	0.3	-0.5	-0.2	0.2	-0.1	-0.3	-0.7	0.1	-0.1	-0.5	SrO
ZrO_2	-0.5	0.8	0.6	0.8	0.6	0.6	0.8		-0.7	0.0	-0.5	0.0	0.1	0.2	-0.3	-0.7	0.0	-0.2	-0.5	ZrO_2
FeO	0.5	-0.5	-0.9	-0.9	-0.9	-0.9	-0.8	-0.7		0.4	0.3	0.3	0.3	-0.4	-0.3	0.2	-0.5	-0.3	-0.1	FeO
CuO	-0.4	0.5	0.1	0.0	-0.1	0.1	0.3	0.0	0.4		-0.4	-0.1	0.8	-1.0	-0.8	-0.6	-0.5	-0.4	-0.6	CuO
Cr_2O_3	1.0	-0.8	-0.3	-0.4	-0.6	-0.4	-0.5	-0.5	0.3	-0.4		0.5	-0.3	0.3	0.2	0.3	-0.2	-0.4	0.0	Cr_2O_3
NiO	0.6	-0.1	-0.3	-0.4	-0.7	-0.3	-0.2	0.0	0.3	-0.1	0.5		-0.3	0.0	-0.5	-0.3	-0.8	-0.8	-0.6	NiO
V_2O_5	-0.3	0.3	0.0	0.1	0.0	-0.1	0.2	0.1	0.3	0.8	-0.3	-0.3		-0.6	-0.6	-0.5	-0.3	-0.2	-0.4	V_2O_5
MnO	0.3	-0.4	-0.1	0.2	0.2	-0.1	-0.1	0.2	-0.4	-1.0	0.3	0.0	-0.6		0.7	0.5	0.5	0.3	0.5	MnO
Y_2O_3	0.1	-0.5	-0.1	0.0	0.3	0.0	-0.3	-0.3	-0.3	-0.8	0.2	-0.5	-0.6	0.7		0.9	0.9	0.8	0.9	Y_2O_3
BaO	0.3	-0.7	-0.5	-0.5	-0.2	-0.4	-0.7	-0.7	0.2	-0.6	0.3	-0.3	-0.5	0.5	0.9		0.6	0.7	0.9	BaO
La_2O_3	-0.3	-0.1	0.3	0.3	0.6	0.3	0.1	0.0	-0.5	-0.5	-0.2	-0.8	-0.3	0.5	0.9	0.6		0.9	0.8	La_2O_3
CeO_2	-0.4	-0.1	0.1	0.1	0.5	0.1	-0.1	-0.2	-0.3	-0.4	-0.4	-0.8	-0.2	0.3	0.8	0.7	0.9		0.9	CeO_2
Nd_2O_3	0.0	-0.5	-0.2	-0.2	0.1	-0.2	-0.5	-0.5	-0.1	-0.6	0.0	-0.6	-0.4	0.5	0.9	0.9	0.8	0.9		Nd_2O_3

Table 5.10 Correlation matrix generated using SPSS v.17.0 software, Group 2, Mirongo

In the samples from both groups, the manganese oxide positively correlates with barium oxide and the rare earth oxides of lanthanum, cerium and neodymium, raising the suggestion that these compounds are entering the system together, most likely in association with the ore. The high values for these compounds also apparent in all the ceramic analyses suggest that these compounds are present in relatively high amounts in the background geology of the area. However, the correlation factor between manganese oxide and these other compounds drops from an average of +0.8 in Group 1 to +0.5 in Group 2 (see also Figures 5.63 and 5.64 below). This difference in the strength of the correlation leads to the possibility of an additional source of manganese oxide in the smelting processes of Group 2, distorting its correlation with other ore-related compounds, especially as a further significant correlation between manganese oxide and yttrium oxide is also apparent in these samples – a correlation that is absent from the Group 1 samples.

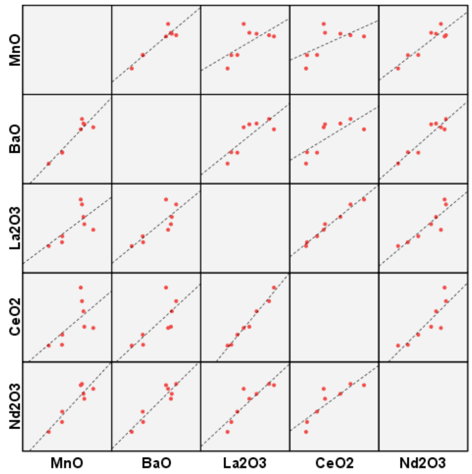


Figure 5.63 Scatter plots showing correlations between MnO-BaO-La_2O_3-CeO_2-Nd_2O_3 in samples from Group 1, Mirongo

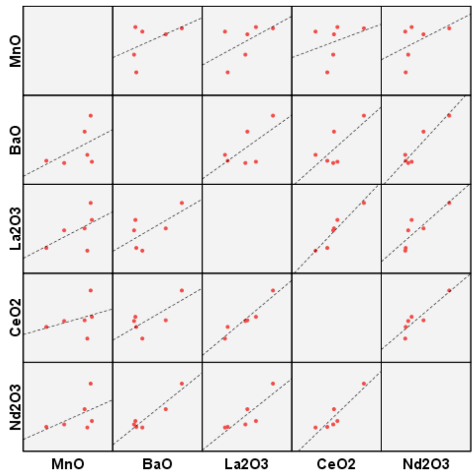


Figure 5.64 Scatter plots showing correlations between MnO-BaO-La_2O_3-CeO_2-Nd_2O_3 in samples from Group 2, Mirongo

The possibility of an addition of a further manganese-rich material would draw a parallel with ethnographic accounts of smelting in the local area. Childs (1998a) states that two ores were used in the smelt: a hard, black ore called *obutale*; and a soft, red ore called *entabo* (also mentioned by Roscoe 1923: 218; and Buchanan 1974a: 102). These were combined prior to the smelt, as the ores were laid out to dry (Childs 1998a: 127-131). It is possible that one of these materials was not an iron ore as such, but rather a manganese-rich 'flux' that improved the outcomes of the smelt. The possible availability of this in the local geological landscape is plausible, as manganese ores often have a close spatial proximity to iron ores (Charlton 2007; Borchert 1970). The manganese-rich nature of many of the slags analysed in this study is testament to this (*cf.* the rest of this chapter and Chapter 7 for a more thorough discussion); manganese-rich iron ores may well be common across the region. The negative correlation between the iron oxide and the manganese oxide in the samples from this group is also likely to some extent to be a reflection of the increased system efficiency of these smelts: the more manganese added to the system, the greater amount of iron oxide is transformed into accessible iron metal.

The strong negative correlation between iron oxide and the fuel ash compounds in Group 2 is also interesting. It is possible that in this system, a charcoal with a relatively raised lime content was being used, so that the more fuel ash entering the system, the more lime, and therefore the less iron is remaining in the slag, resulting in the strong negative correlation observed. Phosphate also correlates strongly with the fuel ash compounds, in both groups, but especially in Group 2. It has been noted that phosphorous can indeed derive in relatively large quantities from fuel ash, rather than an ore as is more often assumed (Schmidt 1997: 126), and unlike at Kyakaturi, where phosphate was present in the excavated ore, in this case, phosphate may be coming from the charcoal used in the smelts.

Two compounds present in the Group 1 samples (titania and cobalt oxide) were below detection limits in the samples of Group 2, which calls for some explanation. The positive association of titania with alumina, silica and magnesia, and especially yttrium oxide (a compound that was present in very low levels in the ceramic analyses, less that 50ppm) identifies a possible relationship between titania and the ore's contribution to the smelts in Group 1. Cobalt oxide, the other compound not present in the Group 2 samples, bears a strong positive correlation with copper oxide and chromia.

The tendency towards high copper levels in all Mirongo slag samples, coupled with a positive correlation between iron and copper oxides in the principal component analysis, also reinforce other ethnographic information that was collected during archaeological fieldwork in Mwenge in the 1990s. It is believed locally that copper ore was once obtained from Rukandu Hill near Mirongo, from the same pits that iron ore was mined from (Robertshaw 1991b). If this is the case (which I found no evidence for), it would offer an explanation as to the elevated copper levels evident in the slag, especially taking into consideration the fact that if copper is present in iron ores, it is generally primarily absorbed into the iron metal, with proportionally little remaining in the slag (Pleiner 2000: 252). Copper was only detected through SEM-EDS analysis in the wüstite phases of the slag, and then only rarely.

In order to gain a more complete understanding of how these smelting systems would have operated, the slag compositions were plotted in a ternary diagram to facilitate comparison with equilibrium phase diagrams. However, because of the unusually high levels of manganese oxide, a simple iron oxide-silica-alumina phase diagram would not be sufficient. As such, in this case silica was plotted against titania and alumina, which both behave in a similar fashion in terms of raising the melting temperature of the slag, and iron oxide, lime and manganese oxide, which also behave similarly, this time lowering the melting point. This was then overlaid on the phase diagram of iron oxide-silica-alumina (Figure 5.65).

From this composite diagram it is only possible to tentatively suggest that the furnaces that produced both groups of slag were operating from a minimum temperature range of around 1100 to 1200°C. As would be expected from the optical microscopy, several samples from Group 1 border the area between wüstite and hercynite, whereas the others from Group 1, and those from Group 2 border the area between fayalite and hercynite.

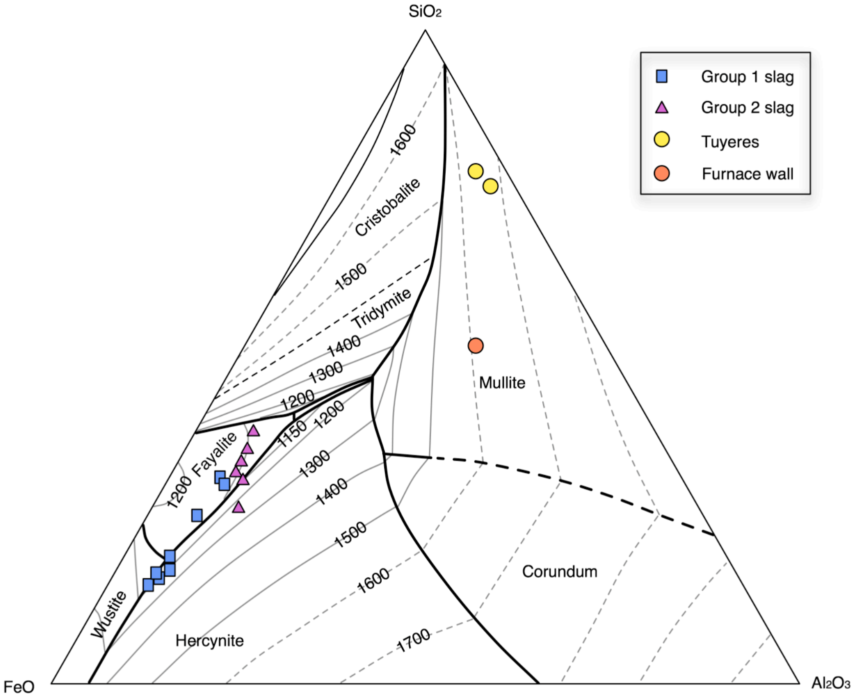


Figure 5.65 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO, with plots for all samples from Mirongo (phase diagram adapted from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%; slag samples are plotted in terms of Al_2O_3+TiO_2 – SiO_2 – FeO+MnO+CaO

Most of the Group 1 samples cluster around Optimum 2, described by Rehren *et al.* (2007: 214) as "the iron-rich eutectic". This would suggest a comparatively lower yield relative to the grade of the ore. Conversely, the location of the Group 2 samples closer to Optimum 1 ("the iron-poor eutectic") would suggest a stronger reducing atmosphere and/or greater contribution of the technical ceramics in these samples, improving slagging and increasing the iron-output of the smelt.

The silica to alumina ratios in the slag (on average 1:3.5-4) compare well with the ratios from the tuyère analyses (again 1:3.5-4), indicative of their contribution to the smelt (Tables 5.11 and 5.12). However, although silica and alumina correlate positively in the slag from Group 1 (with a positive correlation factor of 0.6), they have a negative correlation in the slag from Group 2 (with a correlation factor of -0.8), which indicates that they have a different source.

Group 1	Alumina : Silica	Group 2	Alumina : Silica
Cluster 1		**Cluster 2**	
Slag 1 Middle	1 : 5.1	Slag 1 Middle	1 : 4.5
Slag 3 Middle	1 : 2.7		
Slag 5 Middle	1 : 2.5	**Cluster 3**	
Slag 6 Base	1 : 4.3	Slag 1 Base	1 : 3.1
		Slag 2 Middle	1 : 4.9
Furnace 1		Slag 4 Base	1 : 3.9
Slag 1 Base	1 : 3.2	Slag 5 Middle	1 : 2.3
Slag 1 Middle	1 : 2.9		
Slag 1 Top	1 : 2.8	**Trench 3**	
Slag 2 Middle	1 : 4.4	Slag 1 Middle	1 : 4.2
Average	*1 : 3.5*	*Average*	*1 : 3.8*

Table 5.11 Alumina-Silica ratios for slag samples from Mirongo (calculated from normalised PED-XRF data)

	Alumina : Silica
Furnace Wall	1 : 1.6
Tuyère A	1 : 3.5
Tuyère B	1 : 4.0
Tr2 Pot	1 : 3.1
Tr3 Pot	1 : 2.5
Average	*1 : 2.9*

Table 5.12 Alumina-Silica ratios for ceramic samples from Mirongo (calculated from normalised PED-XRF data)

This suggests that in Group 1 the alumina and silica are coming from the same source, potentially the technical ceramics, although if this was the case, it would require a particularly large contribution of technical ceramics into the smelt (approximately 10kg to produce a 30kg slag block). In Group 2, however, the system appears to be acquiring alumina in larger proportions than silica, raising the possibility that alumina is also present in one of the potential ores. Indeed, in the Group 2 samples, iron oxide and alumina have a positive correlation factor of 0.5, compared to the negative correlation of -0.6 in the Group 1 samples. The marginally higher solidification temperature of one of the Group 2 slag samples does however indicate that the technical ceramics used in this smelt (if they are assumed to be similar to the analysed ceramics from this site) would almost certainly have made a contribution to the melt, given the higher operating temperatures.

To summarise, the slag from Mirongo is, on the whole, typical bloomery slag (Pleiner 2000: 252). However, there appear to be at least two distinct groups of smelting activity at this site, which utilised differing techniques that may have had a pronounced effect on the reduction efficiency of the smelts (*cf.* Charlton *et al.* 2010). These differences are apparent on macroscopic, microscopic and chemical levels. The iron-rich slag of Group 1 is dominated by wüstite, and has an abundance of hercynite. The slag from Group 2 is much leaner, is dominated by knebelite, and has elevated levels of manganese oxide; occasional blocks from this group are plano-convex in profile and bear the impressions of banana pseudostems. The possible addition of a second manganese-rich ore or flux in Group 2 would have lowered the melting temperature and facilitated the chemical separation of the iron from the gangue. The use of manganese-rich material as a fluxing agent in crucible steel production has been noted in Asia (*cf.* Allen 1979; Rehren and Papakristou 2000), but has not previously been documented in bloomery iron production in sub-Saharan Africa.

Unfortunately, it is difficult to say whether these groups of smelting activity were differentiated by time, or different practitioners, or both. However, the date produced from charcoal from the furnace suggests that at least the Group 1 samples are related to the period prior to the development of the Nyoro kingdom. It is only conjecture, but it is possible that the slag from Group 2 (which might have a stronger relationship to recent ethnoarchaeological information that was generated from memories recollected in the twentieth century – specifically regarding the two types of ore) is from a more recent time period. Unfortunately, without the possibility of accurately dating the slag blocks themselves, this is something that for the meantime cannot be pursued further. Some of the other differences in the slag samples from the two groups, particularly the trace elements and the alumina, may be a reflection of localised variations in the background geology and ore body, rather than the conscious selection of different sets of raw materials. Nevertheless, the similarities in the slag samples within the two groups suggest that established and consistent methods were being followed within each of the two groups.

PART THREE: RUGOMBE (RGB)

c. 15th century (1410-1450 cal. AD)

SITE DESCRIPTION

Rugombe is the final site to be discussed within this section, and the third site that was dated to the era preceding the consolidation of kingdoms in the region. The smelting remains are situated within the modern junction town of Rugombe (marked 'Lugombe' on the Department of Lands and Surveys 1:50000 map), which lies approximately 17km due northwest of Kyenjojo, along the main road to Fort Portal. The town is situated on even land that slopes gently to eventually meet marshland to the north, whilst in contrast, steep hills rise to the east and the south. The remains themselves were found on one of the main thoroughfares of the town (on the northern side of the main road), with the remains of a furnace base directly in front of a number of shop fronts (KYS54, Rugombe I, Figure 5.66).

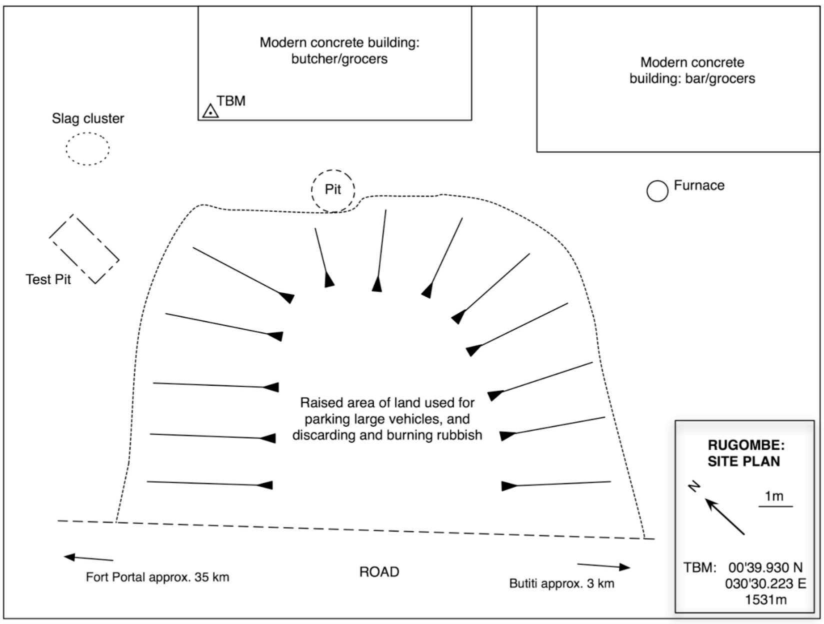


Figure 5.66 Site plan of Rugombe I

Blocks of slag were also dotted around this localised area, most particularly in front of the butcher's shop. A cluster of slag blocks had been noted during the survey, alongside an isolated furnace base and what appeared to be the remains of a large pit.

Close proximity to shops and bars meant that the archaeology had been subject to many years of compaction and disturbance from the footsteps of local residents going about their daily business.

The wider area around Rugombe is, like Mirongo, densely scattered with the remnants of a past iron production industry, with a great many slag scatters and iron ore mining sites located nearby. Several potential sources of ore were identified in the immediate vicinity of Rugombe, which may have provided some of the raw materials that were used in the smelting operations undertaken there. The closest was Rugombe Kasozi (KYS44), on a hillside of Ruha forest, approximately 500m to the southeast of Rugombe trading centre. However, all mining pits at this site had been filled in due to commercial fir tree planting (for the manufacture of matchsticks), and the majority of the pits were now only visible as depressions in the ground. Iron ore mining was also apparent at the nearby sites of Birenge (KYS4, Figure 5.67) and Mukunyu (KYS5), approximately 3km to the southeast of Rugombe. The extensive marsh of Nyakitunga is within a kilometre of the site.

Figure 5.67 Circular iron ore mining pit at Birenge (KYS4)

Further to the discovery of the remains in the trading centre itself, approximately one kilometre along the main road towards Nyamabuga, a single furnace base had been neatly half sectioned during recent road construction activity, and was clearly visible in the newly exposed road cut (Rugombe II). Accompanied by a low-density scatter of slag and pottery sherds, this was assigned survey site reference KYS53 (Figure 5.68). Exploratory excavation was undertaken at this site, and will be briefly described in the following section.

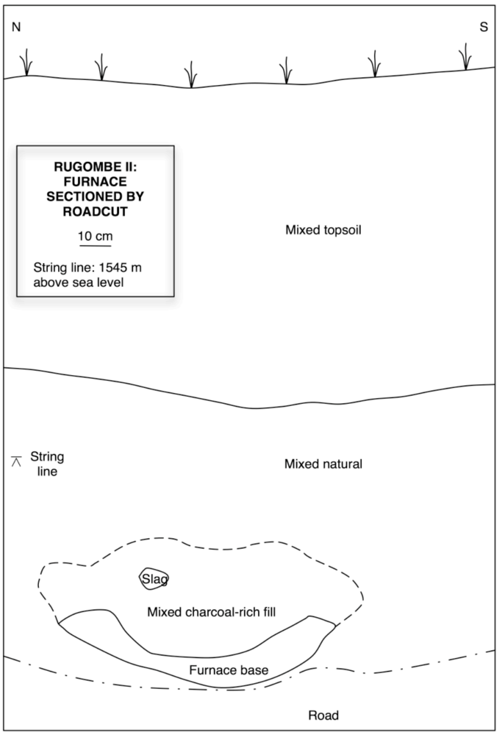


Figure 5.68 Half sectioned furnace base in road cut, Rugombe II

EXCAVATIONS

At Rugombe I, both the furnace base and the pit were excavated, along with a single 1m by 2m testpit (*cf.* Figure 5.66). Samples were taken from four blocks of slag from a cluster of slag blocks situated close to these features. No further slag blocks were apparent in the immediate area, having presumably been cleared away or reused.

Figure 5.69 Furnace at Rugombe I, mid-excavation

Figure 5.70 Furnace at Rugombe I, fully excavated

The furnace of Rugombe I was situated in front of a local bar in the trading centre, and as such the clayey topsoil was heavily mixed with modern finds, such as plastic wrappers, which had been trodden into it over many years. Directly beneath this was a mixed context, with some charcoal and two slag blocks, but also patches of orange clays. The lower context comprised a secure furnace fill – with a high occurrence of charcoal and slag fragments. The fully excavated furnace was approximately 70cm in diameter and 40cm deep (Figures 5.69, 5.70, 5.71). A small 'lip' was noted on the southeastern edge of the furnace wall (on the left of Figure 5.70), where the furnace wall appeared to slope slightly.

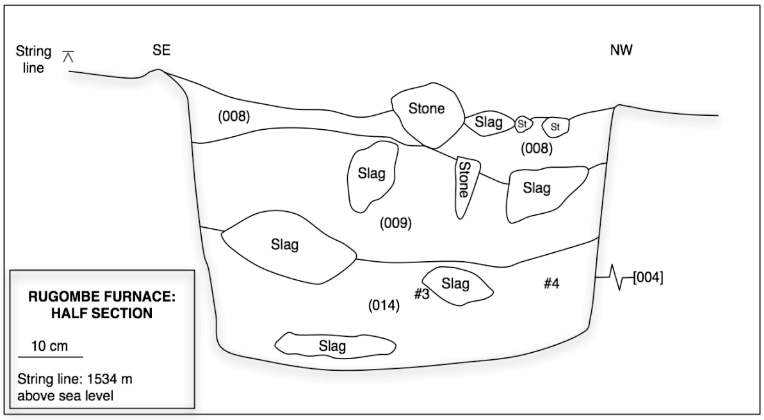


Figure 5.71 Composite profile of furnace at Rugombe I

The furnace base was dug through to confirm the absence of further archaeological deposits beneath the furnace, and the furnace was backfilled. Samples of tuyère, slag, furnace wall and charcoal were taken from this furnace for analysis, in addition to two samples of possible ore that were also excavated from the furnace. A sample of charcoal that was recovered from the secure, lower furnace fill (*cf.* Figure 5.71, marked 3#) generated a radiocarbon date of 479 ±26 BP, which calibrates to 1410-1450 cal. AD with a 95.4% probability (OxCal 4.1; IntCal09; Bronk Ramsey 2009; Reimer *et al.* 2009).

Several metres to the west of the furnace base, the faint outline of what appeared to be a pit was visible on the freshly-trowelled ground surface. The feature was half-sectioned to reveal the lower portions of a pit approximately 1m in diameter, with an irregular base that sloped gently up to the west, and with near-vertical sides. The excavated remains of the feature measured up to a maximum of 30cm in depth. Some disturbance was evident as a result of insect action, and the edges were unclear in places. The lack of finds relating to smelting activity (slag and tuyère fragments) dismissed ideas that this feature might have been a refuse pit for the smelting undertaken nearby, and so the function of this pit remains unclear. It was not possible to ascertain a direct stratigraphic relationship between the different features at this site, and so only the furnace can be reliably attributed to the early fifteenth century.

Finally, a 1m by 2m testpit was also excavated a few metres to the west of the pit feature. The upper layer of mixed topsoil was excavated in 10cm spits, the uppermost layers of which contained much modern debris such as plastic wrappers and so on. The topsoil came down onto a slag-rich deposit, approximately 15cm in depth and containing almost 100kg of small fragments of slag and several pieces of broken tuyère (together totalling approximately 100g). As this trench was directly in the middle of a shopping area, and underneath a patch of grass planted with flowers by local women, it was unfortunately not possible to extend the excavation to see if any features or other associations could be ascertained.

Only a few small and fragmented slag blocks were apparent at Rugombe I. It is likely that as the site is located in a busy shopping area, larger slag blocks might have been broken up or removed from the area. As such, it was only possible to sample from four slag blocks, which all came from an area close to the testpit. These ranged in weight from 1.5 to 15kg, but in all cases features were apparent that allowed them to be categorised as furnace-pit slags. Three slag blocks excavated from the furnace were also sampled, though these were also not comparable to the large, singular blocks seen at other sites in the region and described previously in this chapter.

Directly following the excavations at Rugombe I, a testpit was excavated in the unused scrubland immediately to the east of the furnace base at Rugombe II. A 2m by 3m test-pit was excavated in 10cm spits, in the hope of coming down onto the archaeological layer of smelting activity that was indicated by the remains of the furnace base in the road-cut. Unfortunately however, no such layer was identified during these excavations, and disappointingly, no archaeological features were encountered. A maximum depth of 1.14m was reached before the testpit was abandoned, consisting of an upper mixed deposit with occasional finds of pottery and slag fragments to a depth of between 30 and 40cm, which came down gradually onto clean natural. No further excavations were undertaken at this site.

ANALYTICAL RESULTS AND INTERPRETATION

TECHNICAL CERAMIC ANALYSES

The majority of the tuyère fragments that were found at Rugombe I (from henceforth, referred to as Rugombe) were recovered from the testpit. No tuyères were found in the pit near the furnace. Macroscopic observations and measurements were recorded for all of the recovered tuyères (*cf.* Appendix J). Several examples of tuyère were excavated from the furnace base itself, and two of these were chosen for further chemical and microscopic analysis. A sample of the furnace wall was also taken for analysis. Two samples of domestic pottery (again, both excavated from the furnace pit) were also analysed in the same way (Figures 5.72 and 5.73).

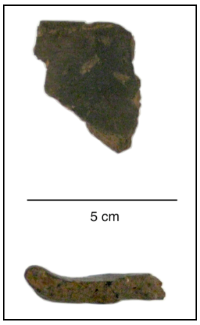


Figure 5.72 Analysed pot, Pot A, Rugombe

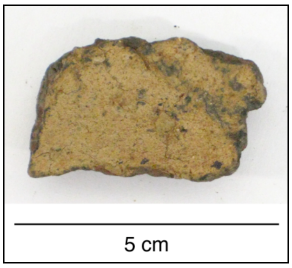


Figure 5.73 Analysed pot, Pot B, Rugombe

The tuyère fragments excavated at Rugombe ranged in colour from dark greys and browns to light beige (Figure 5.74). The average internal diameter of the fragments was 3.8cm (ranging between 2 and 6cm), marginally the smallest of all these early sites, and the tuyères measured on average 1.1cm in thickness. A comparatively small number of tuyères were present at this site, and there were no examples that were very complete. Most showed both grog and quartz inclusions on an initial macroscopic inspection in the field.

Figure 5.74 Examples of tuyère fragments excavated from Rugombe, context (012)

Of the tuyère samples that were chosen for analysis, one (Tuyère A, context 16) had a whitish fabric with a grey outer surface, while the other (Tuyère B, context 17) had a grey fabric and a red exterior surface. They both however looked roughly similar macroscopically – coarse, with large grog temper clearly apparent in both examples (see Figures 5.75 and 5.76).

Figure 5.75 Tuyère A (016) Rugombe (exterior), with a large grog inclusion visible towards the centre of the sample

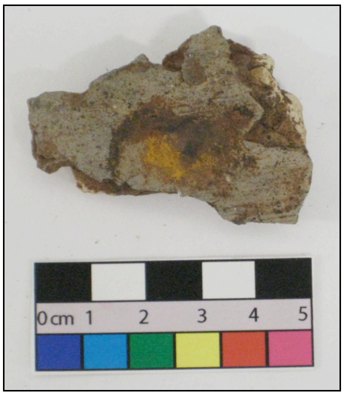


Figure 5.76 Tuyère B (017) Rugombe (interior)

Lengthways striations on the outer surfaces (just visible in Figure 5.76 above) provided a visual indication of how these tuyères had been finished, in a comparable way to the tuyères from other sites in this chapter.

Microscopically the samples also appeared similar, with quartz grains throughout both samples and irregular porosity (Figures 5.77 and 5.78). Tuyère B was particularly low-fired and difficult to polish; quartz grains frequently became loose and damaged the polished surface of the sample.

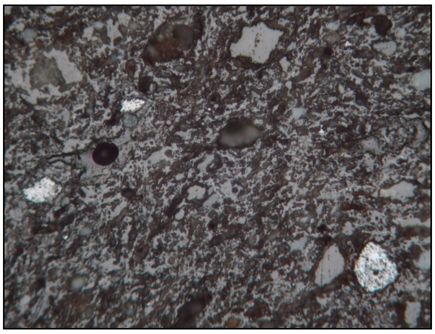


Figure 5.77 Tuyère A (016). Image width ≈ 1mm; PPL

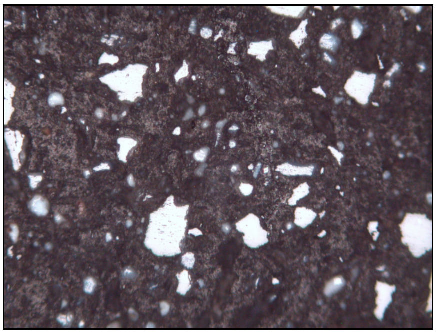


Figure 5.78 Tuyère B (017). Image width ≈ 1mm; PPL

The sample of domestic pottery that was examined microscopically was found to contain many quartz inclusions, which were much more irregular in size than those seen in the tuyère samples (Figure 5.79). Large grog inclusions were also present. The angular porosity visible across the sample provides an indication as to the irregular smoothing of clay to make this ceramic vessel, with porosity running in many directions. This was also apparent in the tuyère samples (see Figure 5.80); on the whole, these ceramics appear quite coarse.

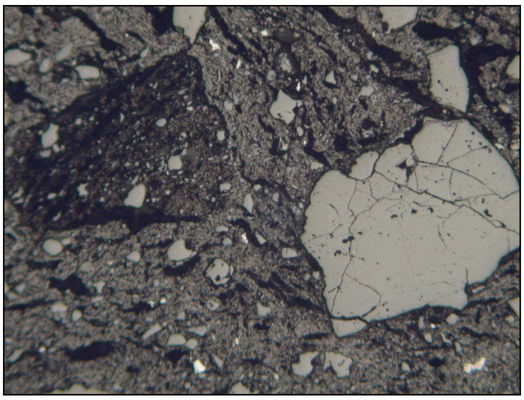


Figure 5.79 Quartz (right) and grog (left) inclusions in domestic pottery sample B from Rugombe. Image width ≈ 2mm; PPL

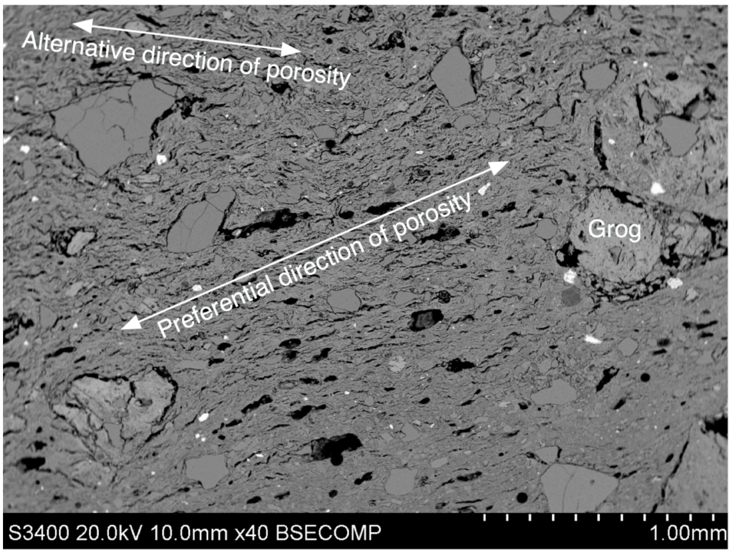


Figure 5.80 BSE image of Tuyère A (016), Rugombe

SEM-EDS spot analyses carried out on some of the inclusions visible in Tuyère A, identified the small bright inclusions as ilmenite ($FeTiO_3$). Other inclusions, besides the quartz, were identified as potassium feldspars.

The PED-XRF analyses, as shown in Table 5.13 and reported in full in Appendix K, revealed that the two tuyère samples were relatively high in alumina (between c. 22 and 28wt%) and correspondingly low in iron oxide (between c. 2 and 4wt%).

The tuyères contained approximately 67-71 wt% silica, giving an alumina to silica ratio of 1:3 in the tuyère from context 016 (Tuyère A) and 1:2 in that from context 017 (Tuyère B). With no other compounds (e.g. lime, iron oxide) making a major contribution to the fabric, these tuyères would have been comparatively refractory.

	Major and minor compounds													
RUGOMBE	Na_2O	MgO	Al_2O_3	*SiO_2*	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO
(RGB)	wt%	wt%	wt%	*wt%*	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
				original	adjusted									
Cluster 1 Slag 1 M	0.33	0.22	7.04	*27.18*	25.00	2.36	0.19	1.02	1.77	0.53	0.06	0.10	0.91	57.60
Cluster 1 Slag 2 M	0.25	≤0.05	4.85	*18.96*	15.36	3.72	0.15	0.08	1.10	0.30	0.04	0.05	1.13	68.25
Cluster 1 Slag 3 T	0.18	/	4.49	*11.61*	8.70	2.25	0.22	0.15	0.58	0.20	0.08	0.10	2.63	76.46
Cluster 1 Slag 4 T	0.25	≤0.05	4.61	*26.23*	23.61	1.59	0.11	0.34	0.53	0.46	0.07	0.11	1.37	63.51
Furnace Slag 1 M	0.21	0.36	10.05	*28.65*	27.21	1.49	0.15	2.27	1.82	/	/	0.09	6.76	45.68
Furnace Slag 2 M	0.23	0.33	7.73	*26.21*	23.59	1.75	0.13	1.62	1.29	0.25	0.01	0.08	3.23	56.26
Furnace Slag 3 M	0.29	0.36	7.50	*26.27*	23.64	1.81	0.13	1.70	1.37	0.19	/	0.07	3.54	55.79
Ore A	≤0.10	/	2.15	*3.13*	2.10	0.94	0.11	0.01	0.06	0.23	0.09	0.05	0.32	92.55
Ore B	≤0.07	/	0.50	*36.60*	36.60	0.15	0.03	/	0.02	0.07	0.01	0.02	0.46	61.80
Furnace Wall	≤0.23	0.16	29.12	*55.68*	55.68	0.22	0.07	0.71	0.14	1.39	0.02	0.03	0.09	11.94
Tuyère (016)	0.35	0.40	21.79	*70.88*	70.88	/	0.03	0.64	0.38	1.67	0.01	0.02	0.05	3.59
Tuyère (017)	≤0.29	0.28	27.82	*67.31*	67.31	0.03	0.05	0.43	0.23	1.40	≤0.00	0.02	0.01	2.01
Pot (008)	≤0.38	0.31	27.51	*64.29*	64.29	0.18	0.06	1.50	0.31	1.42	0.01	0.02	0.02	3.89
Pot (012)	0.19	0.33	21.58	*67.68*	67.68	0.05	0.06	0.37	0.75	2.33	0.03	0.03	0.05	6.34

	Trace compounds														
RUGOMBE	Co_3O_4	NiO	CuO	ZnO	SeO_2	Rb_2O	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	PbO	Analytical
(RGB)	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Cluster 1 Slag 1 M	762	/	149	≤9	/	/	819	99	1569	743	1010	1016	623	/	104.03
Cluster 1 Slag 2 M	728	/	333	27	/	/	1625	106	935	1543	2397	1844	1187	/	108.79
Cluster 1 Slag 3 T	528	/	831	24	/	/	898	102	932	3831	1305	1311	911	/	110.40
Cluster 1 Slag 4 T	672	/	140	14	/	/	532	81	1207	1052	1808	1421	1023	/	104.58
Furnace Slag 1 M	/	/	141	58	/	/	1155	44	726	19208	265	2105	1134	/	108.76
Furnace Slag 2 M	328	/	194	72	/	/	345	31	367	6575	118	511	309	/	107.81
Furnace Slag 3 M	251	/	174	82	/	/	369	29	369	7573	66	426	410	/	109.08
Ore A	960	/	425	60	390	/	61	/	497	95	487	279	263	/	91.45
Ore B	921	/	37	54	/	/	93	/	211	184	626	409	187	/	104.51
Furnace Wall	185	54	68	135	/	71	28	/	752	483	228	543	130	15	83.30
Tuyère (016)	83	61	52	63	/	29	43	/	746	428	165	250	162	43	102.22
Tuyère (017)	48	38	80	37	/	45	42	/	729	579	217	250	214	62	88.70
Pot (008)	70	49	66	71	/	92	60	/	767	462	172	263	181	40	90.50
Pot (012)	135	77	91	76	/	32	96	/	799	395	82	129	≤89	7	93.04

Table 5.13 PED-XRF compositional data for all samples from Rugombe, normalised to 100%. All values are the average of the three analyses of each sample reported in Appendix K. 'Analytical total' shows the analytical total prior to normalisation

SEM-EDS microanalysis carried out on Tuyère A (Table 5.14) was used to examine the composition of the ceramic matrix free from inclusions, as well as confirming the composition of these inclusions. These analyses presented a ceramic matrix with an average of 28wt% alumina and 64wt% silica, giving a ratio of just over 1:2.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	FeO	(wt%)
Tuyère A	0.2	0.4	28.1	64.2	0.0	1.1	0.5	1.5	4.0	

Table 5.14 Averaged SEM-EDS compositional data for Tuyère A, Rugombe, normalised to 100%

Although overall the tuyères are similar in composition, they tended to be not as closely matched as those from other sites, particularly regarding the oxides of zinc, copper and rubidium. The tuyères also differed significantly from the samples of pot and the furnace wall. This is best illustrated in the line charts below (Figures 5.81 and 5.82).

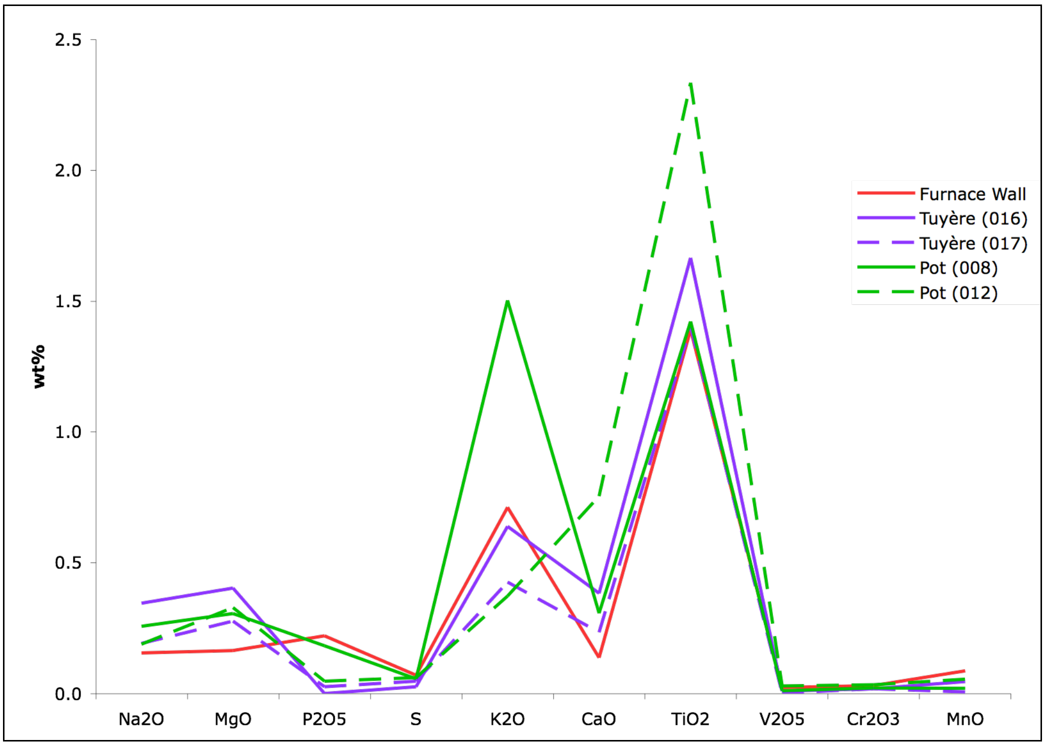


Figure 5.81 Line plot showing major and minor compounds (less Al_2O_3, SiO_2 and FeO) of analysed ceramics from Rugombe, calculated from PED-XRF data normalised to 100%

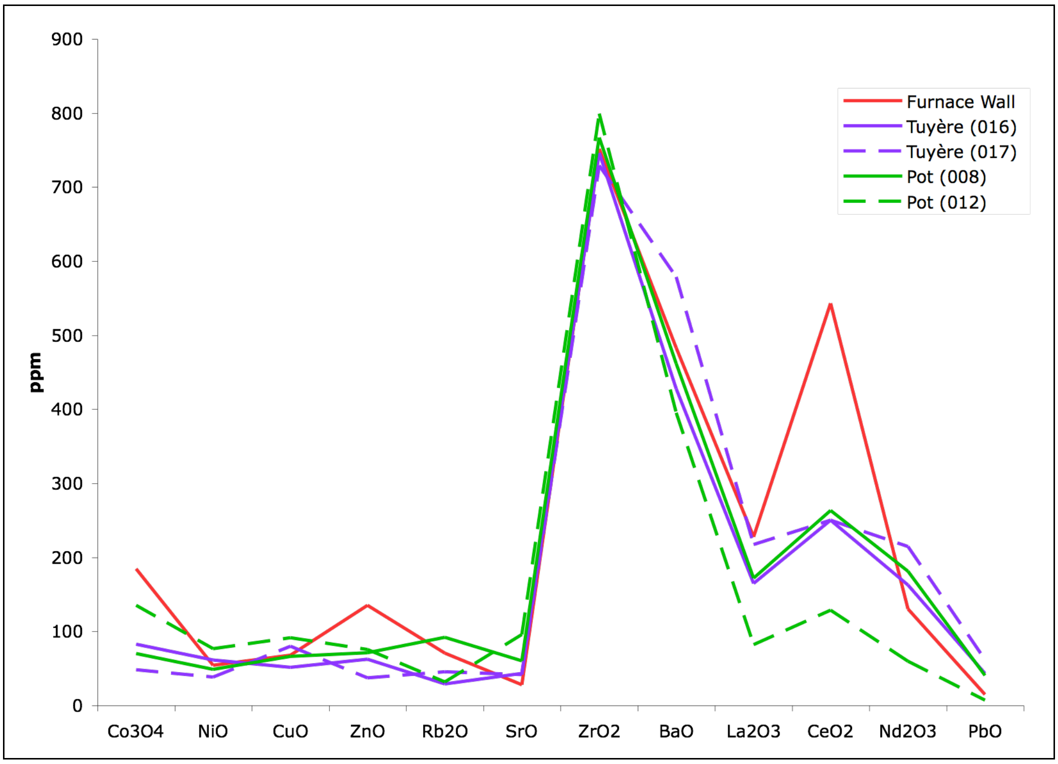


Figure 5.82 Line plot showing trace compounds of all analysed ceramics from Rugombe, calculated from PED-XRF data normalised to 100%

The samples of domestic pottery are dissimilar to each other as well as being dissimilar to the tuyère samples, although they appear in general terms to be of a similarly refractory nature with alumina contents of up to 28wt%.

In this instance, the sample of furnace wall (with an iron oxide content of 12wt%) does not seem to have been as contaminated by the furnace charge as at other sites and appeared not to contain slag temper, and as such can provide some secure indication of the original furnace wall composition, which would also have been highly refractory with an alumina content of nearly 30wt%. However, the differences in both minor and trace compounds suggest that slightly different clays were being sourced for the furnace wall and the tuyères, as well as for the domestic pottery in this area.

Although from a small sample size, the technical ceramics at this site do not appear to be as uniform as at the other sites, and they tend to have been more coarsely manufactured. Variations in the bulk chemical values of the analysed samples suggest that the clays selected for this purpose are potentially being obtained from a slightly different source, perhaps a different region of a single body of clay, or the methods of manufacture were not as regulated as at other sites.

METALLURGICAL ANALYSES

MACRO-DESCRIPTIONS

Due to the limited presence of large or complete slag blocks at Rugombe, unfortunately only a small number of slag samples were examined for the purposes of reconstructing smelting activity at this site. Three large slag fragments that had been excavated from the furnace were chosen for sampling, along with four further large slag fragments from the slag cluster shown on Figure 5.66. These four blocks were recorded in detail (Table 5.15), and all of these, plus those from the furnace, were analysed using PED-XRF. As no large contiguous slag blocks were found, multiple samples were not analysed from any of the slag blocks at Rugombe.

The slag from Rugombe was much smaller and more irregular than that found at other Mwenge sites (Figures 5.83 and 5.84). It consisted both of broken fragments of slag, and complete, unbroken (i.e. with no fractured edges) but small and generally amorphous slag masses. However, due to the presence of particular morphological features on some of these fragments (e.g. flattened bases) and the lack of flow structure that would typically be associated with tapped slag, it was possible to suggest that these slag fragments were likely to have formed within a furnace pit, especially as they appear broadly consistent with the excavated furnace example.

		Complete	Width a	Width b	Depth	Weight	Samples				
Cluster	Slag #	block?	cms	cms	cms	kg	Top	Middle	Bottom	ED-XRF	OM/SEM-EDS
1	1	Y	13	10	11	2		✔		✔	
	2	N	11	13	15	1.5		✔		✔	✔
	3	N	28	21	21	14	✔		✔	✔	
	4	Y	22	19	30	11	✔		✔	✔	
Furnace	1	Y	20	15	11	11		✔		✔	✔
	2	Y	14	13	10	9		✔		✔	✔
	3	Y	13	11	6	5.5		✔		✔	

Table 5.15 Summary of macroscopic information recorded for slag blocks from Rugombe

Like the slag blocks from Kyakaturi, these slag fragments had a slight greenish tinge, but this was much less pronounced, and they tended to be yellow-green or greenish-grey. All the slag blocks that were examined bore the impressions of medium (and less frequently, large) reeds or grasses.

Figure 5.83 Top of Cluster 1, Slag 3, Rugombe

Figure 5.84 Profile of Cluster 1, Slag 4, Rugombe

Several of the slag blocks at this site were also a lot more lumpy and porous than at other sites (Figure 5.84). This might suggest a less fluid slag and a smelting system with a relatively lower operating temperature, meaning that the slag did not collect in the pit as a single contiguous block. This is consistent with the arrangement of the slag that was excavated from the furnace.

ANALYSIS

The PED-XRF results, presented in Table 5.13 and reported in full in Appendix K, show that – as expected – all the slag samples that were analysed were consistent with bloomery iron slag, composed primarily of silica and iron oxide.

All components, whether major, minor or trace, showed considerable variation. Iron oxide ranged from 46wt% to 76wt%, and was lowest in those samples from the furnace (which averaged at 53wt%). Alumina levels varied from 4wt% to 10wt%, with the highest values in the furnace slag samples. Silica also showed considerable variation, ranging between 9wt% and 27wt%. As such, the alumina to silica ratios were also highly variable. On average, the ratio was 1:3, but this covered a wide range from 1:2 (C1S3T) to 1:5 (C1S4T). Like both Kyakaturi and Mirongo, phosphate was also quite high (ranging between 1 and 4wt%).

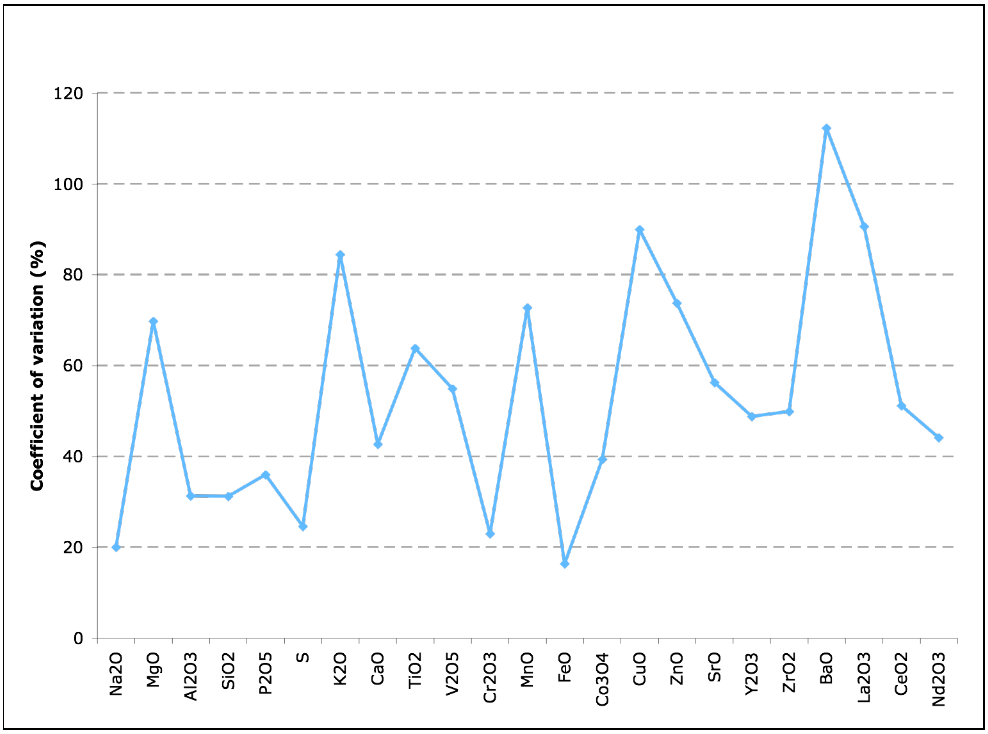


Figure 5.85 Coefficients of variation for all compounds in the sampled slag blocks from Rugombe, calculated from PED-XRF data normalised to 100%

Figure 5.85 demonstrates just how much variation there is in all compounds across the sample set. Only iron oxide has a CV that falls beneath 20%; the majority of the remaining compounds have CVs of over 50%. Measurements of barium oxide cover a particularly large range. In sample C1S1M, the reading is 743ppm; in sample FS1M, the reading is almost 2wt%. Although this is an inter-smelt comparison, and as such the variation will always be considerably higher than that within a single smelt, the extent of variation within this sample set is still worth noting. Whilst not as pronounced as the CVs seen across the site of Mirongo (Figure 5.49), they are much higher than those seen at Kyakaturi (Figure 5.17). However, it is also important to note that the porosity illustrated in some of the photomicrographs (e.g. Figure 5.88) is likely to be due to corrosion, which will further increase the coefficients of variation presented here.

Nevertheless, principal component analysis was employed in order to assess whether there were any meaningful patterns in this variation (Figure 5.86 and Appendix L). As can be seen in Figure 5.86 below, the slag samples from the furnace appeared spatially distinct from those from Cluster 1, separated along PC1. The furnace samples tended to be richer in alumina, manganese oxide[2], potash and barium oxide and depleted of iron oxide and several minor and trace compounds, whereas the samples from Cluster 1 tended to show the reverse.

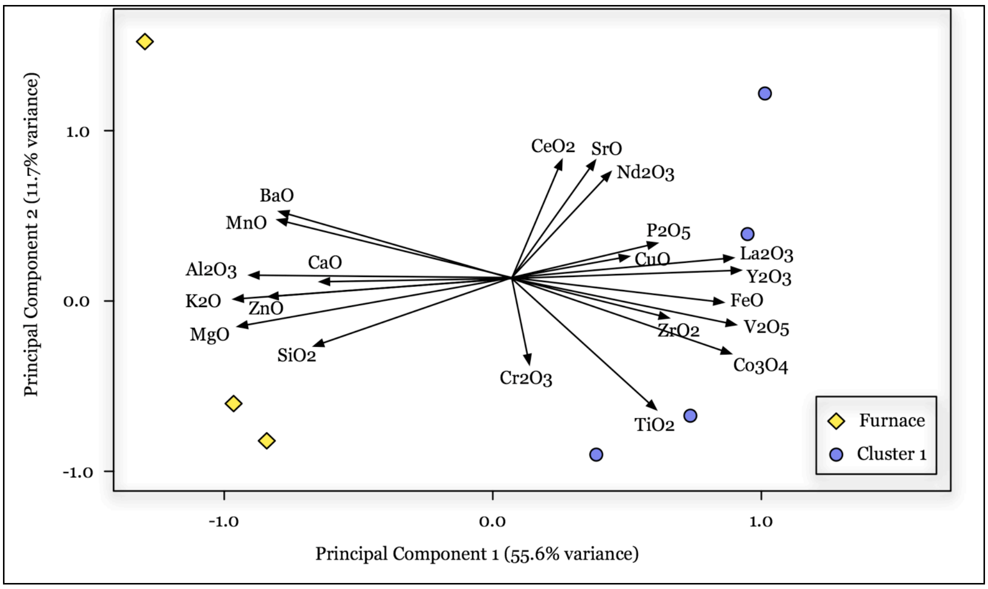


Figure 5.86 Graph of Rugombe slag samples in principal component space (PC1 vs. PC2)

[2] Again, the difference in manganese oxide content of these samples is likely to be greater than the PED-XRF results suggest, with significant underestimation in the samples richer in manganese oxide.

Although there are too few samples to form a statistically secure pattern, the disparity that is apparent between the two compositional groups is noteworthy but not dramatic. When recalculated separately, the coefficients of variation of the two sub-groups do show a tendency to decrease, with the occasional outlier (Figure 5.87). This seemingly compositional grouping of the samples could either be an indication of a slightly altered technological process or minor changes in raw materials (due, for example, to variations in ore bodies – particularly if considering values of manganese oxide) or different practitioners over the years of smelting at that site. This in turn raises the possibility that the slag blocks from the slag cluster are not necessarily immediately related to the slag blocks from the furnace. Once again, no contextual information was able to link the two groups at the point of excavation.

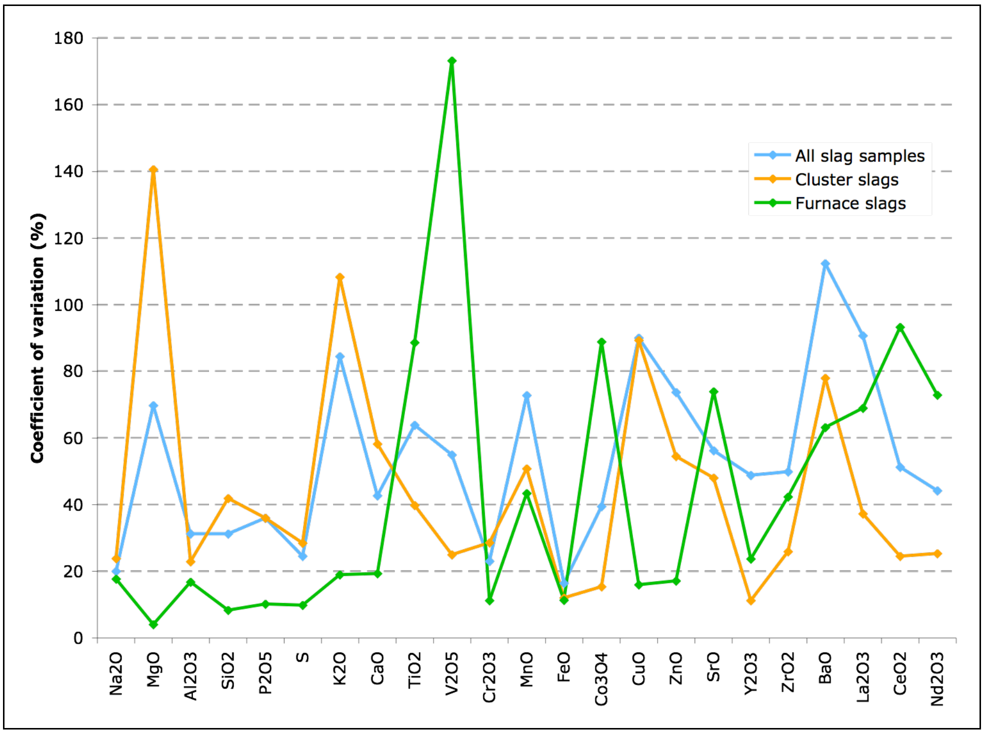


Figure 5.87 Coefficients of variation for all compounds in the sampled slag blocks from Rugombe – combined and separated into groups – calculated from PED-XRF data normalised to 100%

The small size of the slag blocks from the cluster means that there is no guarantee that they were not brought to the site from elsewhere at a different time; a greater number of larger slag blocks that are inconvenient and troublesome to move might be more of an indication that they were produced where they were found. Whilst undertaking survey and talking to local people about slag, there were several indications as to why slag blocks might be moved from place to place. Not only were the reasons touched upon in earlier chapters regularly mentioned (e.g. that they were – and are – used for building materials, for houses and road, even for rockeries in gardens, see also Figure 6.2 and 6.3), occasionally there was a more unusual suggestion. During survey in the north of Mwenge, in an area with very little slag, an old woman whose land we passed through asked that if we did manage to find any slag nearby perhaps we could give her some – she believed that it was good to have in the house to keep ants away. Clearly there are a variety of reasons why slag might be moved around the landscape, and recognition of this is an important factor in assessing the level of information that can be gleaned from slag scatters.

Under microscopic examination, the two samples from the furnace were very porous, despite both originating from the centre of the slag block. However, they were relatively homogenous, although there was some variation in crystal size in sample FS2M. Both samples were dominated by approximately 80area% fayalite, on the whole blocky in shape (Figure 5.88), indicating a relatively slow cooling time consistent with that of furnace-pit slag. A line of more feathery fayalite ran across the width of sample FS2M (Figure 5.89), although there is a transition to blockier crystal size on both sides of this line.

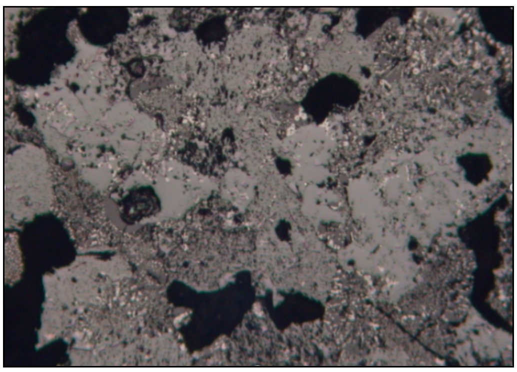


Figure 5.88 Photomicrograph showing overview (and porosity, black) of sample FS2M, Rugombe. Image width ≈ 1mm; PPL

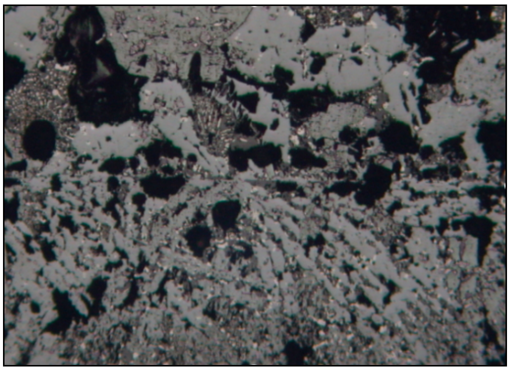


Figure 5.89 Photomicrograph showing transition line between blocky fayalite and more feathery fayalite in sample FS2M, Rugombe. Corrosion is visible attacking the glassy matrix. Image width ≈ 1mm; PPL

Other phases present in sample FS1M included pinkish hercynitic spinels (c. 8area%) and eutectic wüstite (c. 3area%, with rare occurrences of wüstite developed into globular dendrites) in a glassy matrix (c. 8area%). Irregularly distributed across the sample were some rare (c. 1area%) dark grey crystals, which in some instances were acicular. No microanalysis was undertaken on this sample, but similar phases in sample FS2M were found to be leucitic. Occasional (<1area%) droplets of metallic iron were also present across the sample (Figures 5.88 and 5.89).

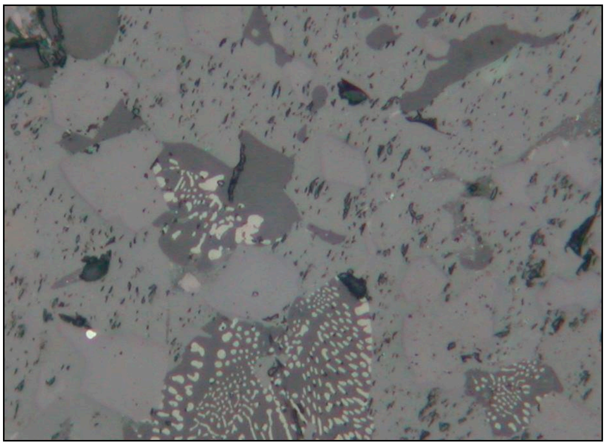


Figure 5.90 Photomicrograph showing blocky fayalite (mid grey), hercynite spinels (pinkish grey), metallic iron (white), and eutectic wüstite (light grey) in a glassy matrix (dark grey). FS1M, Rugombe. Image width ≈ 0.25mm; PPL

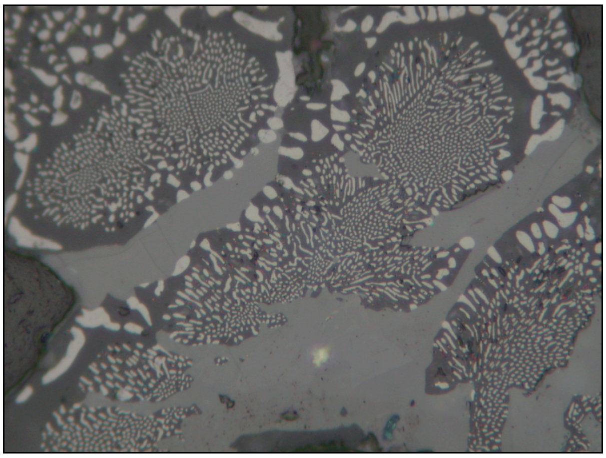


Figure 5.91 Photomicrograph showing eutectic wüstite (light grey) exsolving from a glassy matrix (dark grey) with some fayalite (mid grey). FS1M, Rugombe. Image width ≈ 0.2mm; PPL

FS2M was similar to FS1M (*cf.* Figure 5.92), though with a slightly higher proportion of more well developed wüstite, which corresponds to the higher reading for iron oxide in the bulk chemical analysis of this sample. Microanalysis of this sample revealed that the fayalite on average contained approximately 4-5wt% manganese oxide, as well as limited contributions (generally <1wt%) of magnesia and lime. The hercynite also had some substitution of manganese oxide (c. 1-2wt%) and titania (c. 1wt%) for alumina, and the wüstite also contained 1-2wt% manganese oxide. The glassy matrix was close to the composition of leucite, with some iron oxide (c. 2-4wt%) and barium oxide (c. 1wt%).

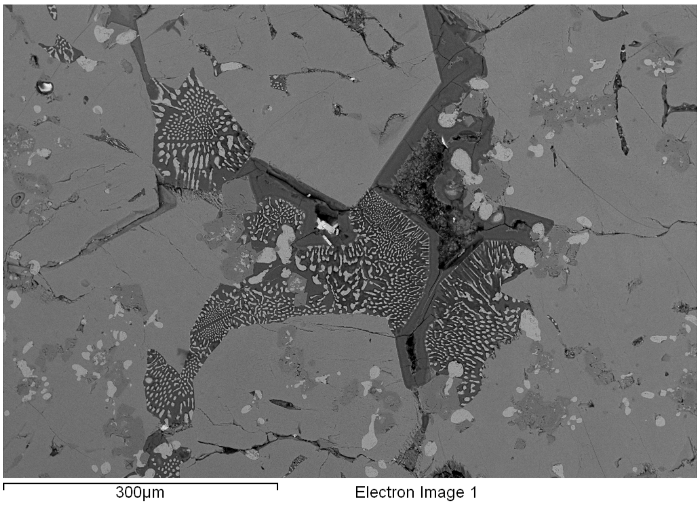


Figure 5.92 BSE image of FS2M, Rugombe, showing fayalite (mid grey), hercynite spinels (darker mid grey), and wüstite (light grey) exsolving from a leucitic matrix (darkest grey)

The sample from Slag 2, Cluster 1 (C1S2M) was also very homogeneous, but less porous than the previous samples. It contained similar phases to the samples from the furnace, but in different proportions and with different crystal sizes (Figure 5.93). Most striking was the higher proportion of wüstite, which covered around 30area% of the sample, and the very low proportion of glassy matrix (approximately 5area%). In addition to this were darker, angular crystals of hercynite, and occasional droplets of iron. Microanalysis showed that the fayalite was relatively pure, with some substitution of phosphate (c. 1-3wt%), lime (≤0.6wt%) and manganese oxide (c. 2wt%). The hercynite contained titania (c. 1-3wt%) and manganese oxide (c. 0.5-1wt%) in addition to alumina and iron oxide.

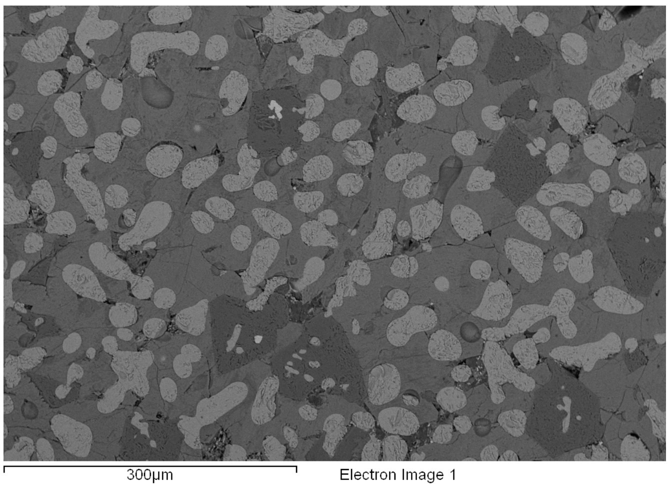


Figure 5.93 BSE image of C1S2M, Rugombe, showing fayalite (mid grey), hercynite spinels (dark grey), and wüstite (light grey)

A bluish line of degraded iron (possibly an iron hydroxide with phosphorous) was visible along one of the edges of the cut sample (Figure 5.94), which was already known from the bulk analysis to be rich in iron. However, the structure of this iron foil was dissimilar to that observed in slag from Laikipia (Iles and Martinón-Torres 2009) or Buhaya (Schmidt 1997: 116). Instead, the iron bore the shape of conjoined spheres of iron droplets, likely a redeposition of droplets of corroded (hydrated) iron that migrated from elsewhere in the slag and precipitated on the surface of the slag.

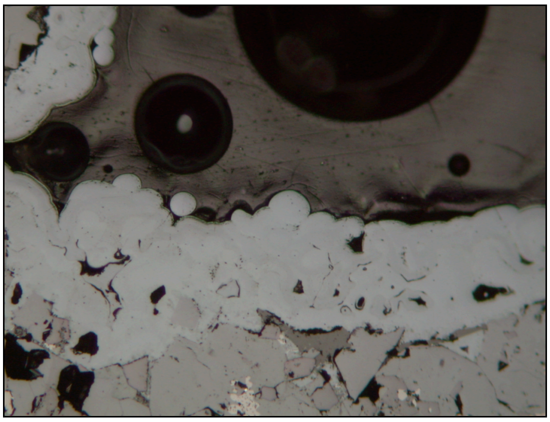


Figure 5.94 Photomicrograph showing line of degraded iron (bluish-grey) C1S2M, Rugombe. Image width ≈ 2mm; PPL

Upon examination at high magnification, the glassy matrix was seen to comprise several phases (Figure 5.95). A number of spot and area analyses of this matrix yielded a variety of unusual compositional results, but mostly they gave results enriched in iron oxide (c. 30-50wt%) and phosphate (c. 17-45wt%), with contributions of varying proportions of alumina, silica, potash, lime, titania and oxides of manganese, barium and tungsten. The high iron content of this matrix, along with the prevalence of wüstite (and corroded iron) in this sample accounts for the high levels of iron oxide in the bulk chemical analysis.

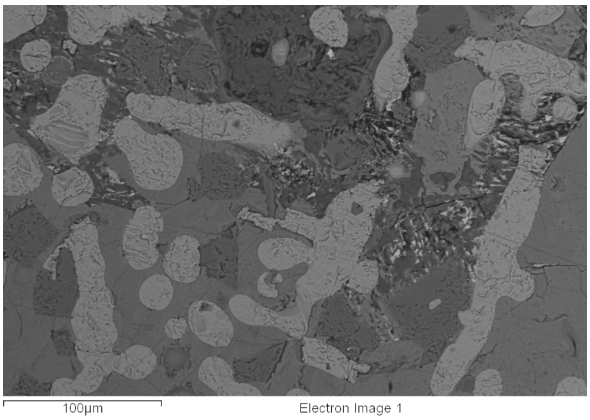


Figure 5.95 BSE image of C1S2M, Rugombe, showing fayalite (mid grey), hercynite spinels (dark grey), and wüstite (light grey)

Two small fragments of ore that were excavated from the furnace at Rugombe were selected for analysis. Both were analysed using PED-XRF to generate bulk chemical data; one was also prepared for further examination by optical microscopy. Although, on weathering, one had corroded to a more yellowish colour (Ore A) and one to a more reddish colour (Ore B, Figure 5.96), once cut, they appeared very similar internally (see Figure 5.97).

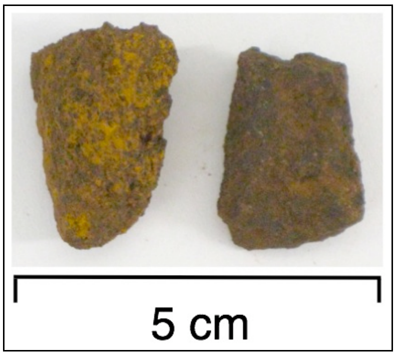


Figure 5.96 Fragments of unreduced ore, excavated from the furnace at Rugombe. Ore A is on the left (yellowish), and Ore B is on the right (reddish)

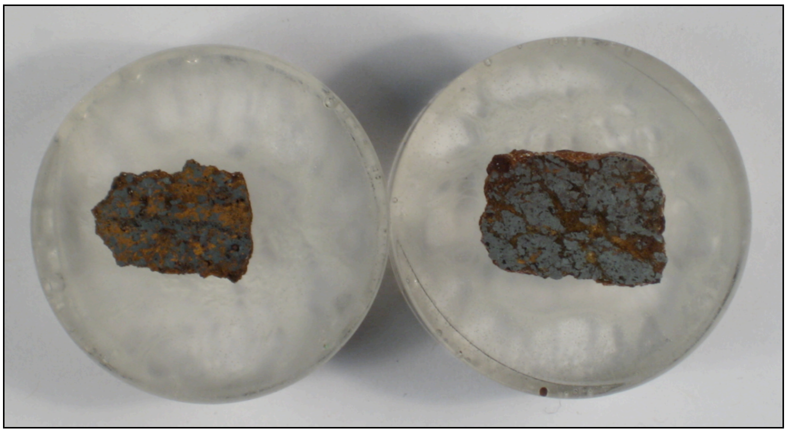


Figure 5.97 Mounted and polished samples of ore from Rugombe. Ore A is on the left, Ore B is on the right

The results of the bulk chemical analysis on the two samples showed some considerable variation in composition (Table 5.13, and Appendix K). Both have viable iron oxide contents, yet Ore A is particularly rich, with an iron oxide content of approximately 93wt%, as compared to 62wt% in Ore B.

Photomicrographs of both samples (Figures 5.98 and 5.99) demonstrate the porous nature of these materials, which suggests that they could easily have been broken into small pieces prior to smelting, and that they would have been readily penetrated by the reducing gases within the furnace during the smelt itself.

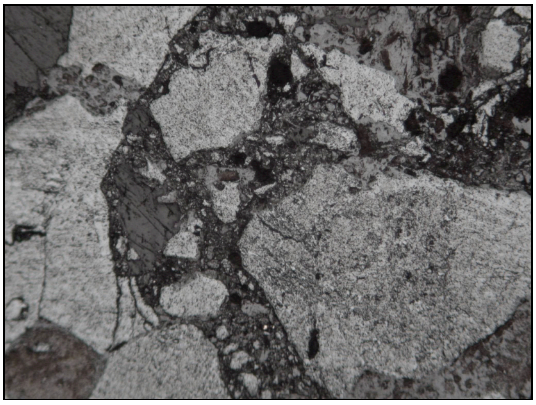


Figure 5.98 Photomicrograph of Ore A, Rugombe, showing haematite crystals. Image width ≈ 1mm; PPL

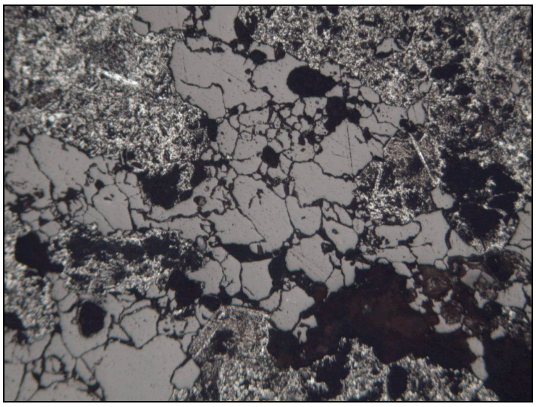


Figure 5.99 Photomicrograph of Ore B, Rugombe, highlighting prolific quartz (mid grey, centre). Image width ≈ 1mm; PPL

The variation in the iron content of the two samples is mostly explained by the accompanying proportions of silica, as the quartz content of Ore B was relatively high (compare Figures 5.98 and 5.99); combined silica and iron oxide contents of both samples approximated 95-98wt%. Nevertheless, slight variation is apparent in the remaining minor and trace elements (see Figures 5.100 and 5.101). Ore minerals, like other materials for smelting, are generally chosen with great care due to the high cost of failure of a smelt. As such it is unlikely that one of these ore fragments was included in the smelt by accident, particularly as their weathered appearance is noticeably different. Instead, it is feasible that both of these types of ores were chosen purposely for the smelt, with perhaps the high silica content of one complementing the richness of the other.

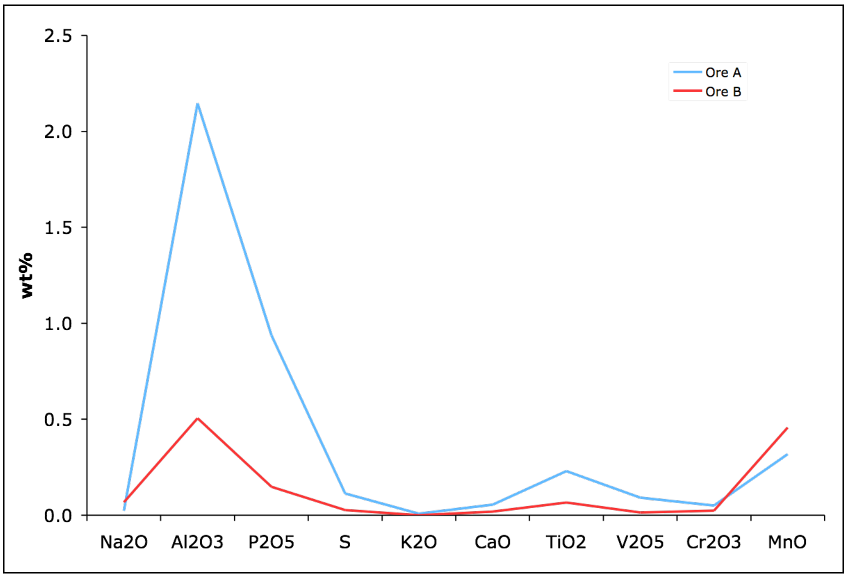


Figure 5.100 Line plot showing minor compounds of ore samples from Rugombe, calculated from PED-XRF data normalised to 100%

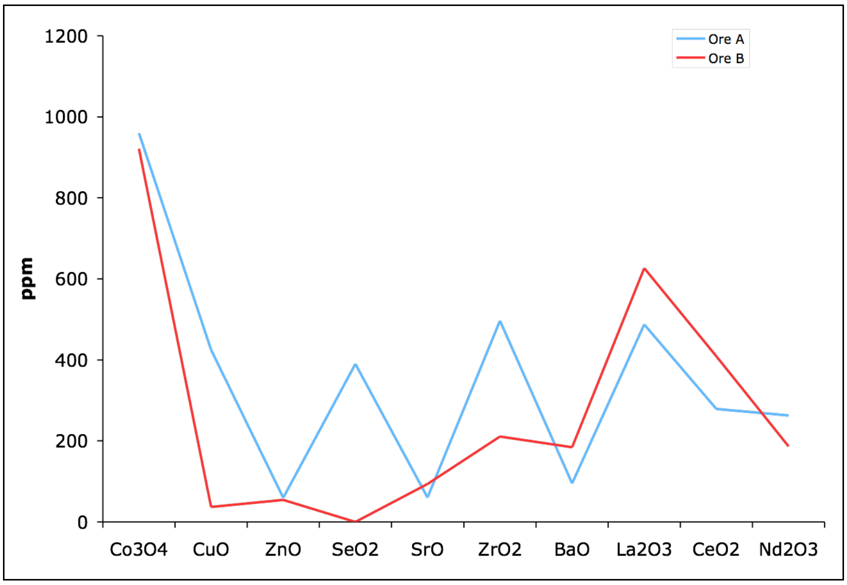


Figure 5.101 Line plot showing trace compounds of ore samples from Rugombe, calculated from PED-XRF data normalised to 100%

Discussion and Summary

The elevated levels of cobalt and copper oxides present in the Rugombe ore samples would explain the raised levels of these compounds in the bulk chemical analysis of the slag blocks from this site; however, there are still some compounds which appear enriched in the slag, but which are seemingly not explained by the ore analyses.

Alumina is present in high proportions in the slag, yet in very low proportions in the ore samples. However, contributions from the technical ceramics may have served to feed alumina into the system. The alumina to silica ratios of the technical ceramics mirror those of the slag blocks (excepting sample C1S4T), which supports this notion (*cf.* Craddock *et al.* 2007)[3]. Refiring experiments on ceramics with comparable compositions (particularly Late Medieval crucible 25482, Freestone and Tite 1986: 45), showed the development of fine bloating pores (<10μm) at temperatures of up to 1200˚C; plotting the slag samples on a ternary phase diagram (Figure 5.102) showed that the slag would have become liquid at a minimum temperature of around 1150-1200˚C. As such, it is probable that temperatures would have been reached that would have enabled the technical ceramics to make a contribution to the slag formation.

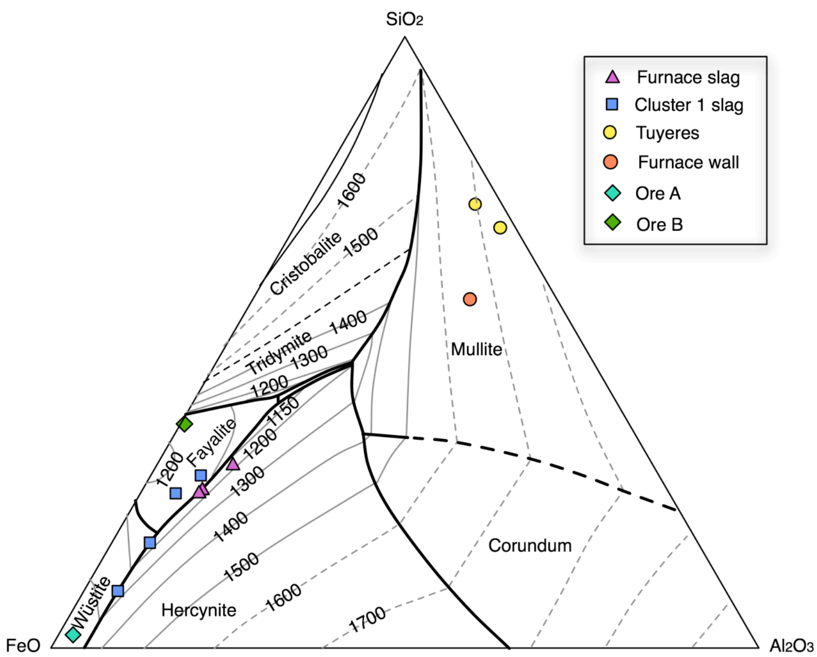


Figure 5.102 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO, with plots for all samples from Rugombe (phase diagram adapted from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%; slag samples are plotted in terms of $Al_2O_3+TiO_2$ – SiO_2 – FeO+MnO+CaO

[3] Although this does not allow for extra silica entering the system from a possible ore (e.g. Ore B).

Plotting the samples onto the phase diagram also confirmed and extended the knowledge gained from the optical microscopy and the bulk chemical analysis. The two samples from Cluster 1 that had the lowest silica readings (C1S2M and C1S3T) were situated on the low temperature trough between wüstite and hercynite. This corresponds well with the results of the optical microscopy of sample C1S2M (*cf.* Figure 5.93). The remaining samples from Cluster 1, with lower iron oxide readings, would have favoured the formation of fayalite.

The samples from the furnace, however, were in the region of the diagram that favoured the formation of hercynite, and this was also reflected in the optical microscopy of samples FS1M and FS2M, which showed higher proportions of hercynite (comparable to fayalite), corresponding with elevated alumina in the bulk chemistry. Hercynite has a high melting point, and its presence within these slag samples indicates that the slag would have been relatively viscous. This is consistent with the macroscopic appearance of the slag blocks from this site.

Manganese oxide (which registers up to 7wt% in the samples from the furnace) is the last aspect of the bulk chemical analysis to be explained. These amounts cannot be accounted for either by contributions from the technical ceramics (or fuel ash) or the samples of ore that were analysed. This disparity may be because the ore sample that was analysed was not representative of that which was being used in the smelting, or that a further material – with an elevated manganese content – was being added to some of the smelts. In the samples from Cluster 1 (where the levels of manganese oxide were comparatively low), manganese oxide correlated strongly with iron, copper and barium oxides (associating it with the iron ore portion of the charge), and had a negligible correlation with the rare earth compounds (La_2O_3, CeO_2, Nd_2O_3) (Figure 5.103).

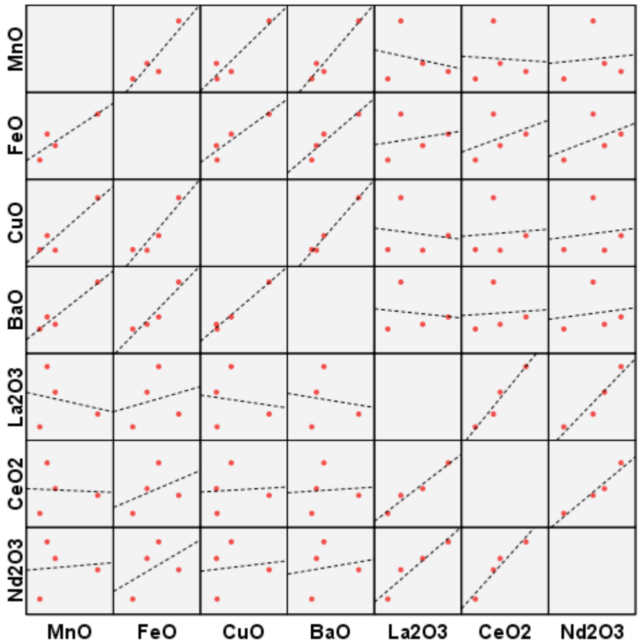


Figure 5.103 Scatter plots showing correlations between MnO-FeO-La_2O_3-CeO_2-Nd_2O_3 in samples from the slag cluster, Rugombe

In the samples from the furnace, however, which had on average higher manganese oxide readings, manganese oxide had a strongly negative correlation with the ore-related oxides (cobalt, copper, iron oxides; Figure 5.104). Intriguingly, in this case, manganese oxide shared positive correlations with many of the same compounds as the samples from Mirongo Group 2 (BaO, La_2O_3, CeO_2, Nd_2O_3, *cf.* this chapter, Part Two), which raises the possibility that a similar technological approach is being employed here, although as this is such a small sample set, this hypothesis cannot be taken much further.

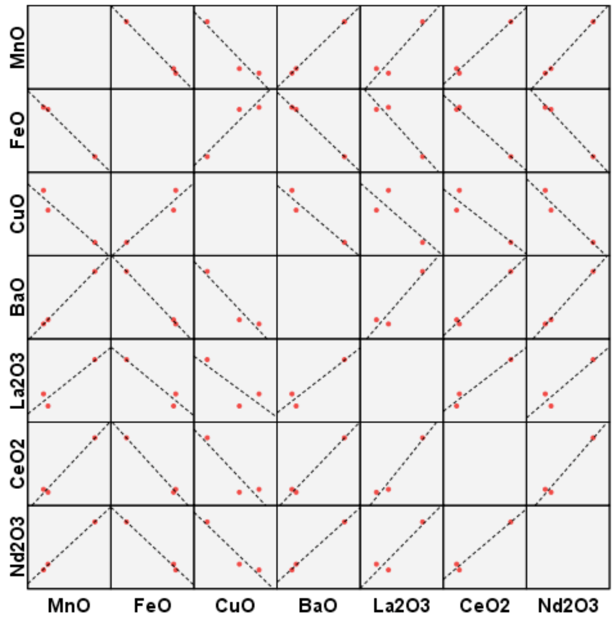


Figure 5.104 Scatter plots showing correlations between MnO-FeO-La_2O_3-CeO_2-Nd_2O_3 in samples from the furnace, Rugombe

In summary, it appears that the slag associated with the furnace (and therefore the fifteenth century radiocarbon date) is the product of a smelting system enriched with manganese oxide and alumina that resulted in a very lean slag. It appears that a rich ore was being used with coarse technical ceramics that would have contributed to the melt, which resulted in the effective production of iron at this site. The scale of the iron production cannot be estimated from the surviving remains, yet the extent of mining for iron ore on neighbouring hillsides suggests that it has been relatively extensive at some point in the past. The slag from the surface cluster of slag blocks is broadly similar in composition to that excavated from the furnace, although it has some minor distinctions from the furnace slag, appearing to be the result of a less efficient process, evidenced in the significantly higher iron oxide levels and correspondingly lower levels of manganese oxide and alumina in these samples.

PART FOUR: INITIAL SUMMARY AND DISCUSSION, EARLY MWENGE SITES

So far, the analyses of the earliest sites to be examined within the confines of this research have all been presented. The results revealed that bloomery smelting was being undertaken across central Mwenge in the fourteenth and fifteenth centuries, employing small pit furnaces to smelt iron. Approaches and materials varied slightly across the sites, which is possibly a reflection of responses to localised differences in resources: at Kyakaturi, a very rich ore was used in conjunction with a quartzitic flux; at Mirongo, two types of smelting were identified – one utilising a manganese-rich material in addition to (a manganese-bearing) iron ore (although this is not necessarily attributable to this time period); and at Rugombe, only a few kilometres away, a similarly manganese-rich iron ore charge was being used in the early to mid fifteenth century. There was no specific evidence for ritual activity, though the repeated nature of smelting methods was implied by the similarities in bulk compositions of slag blocks within sites and/or clusters.

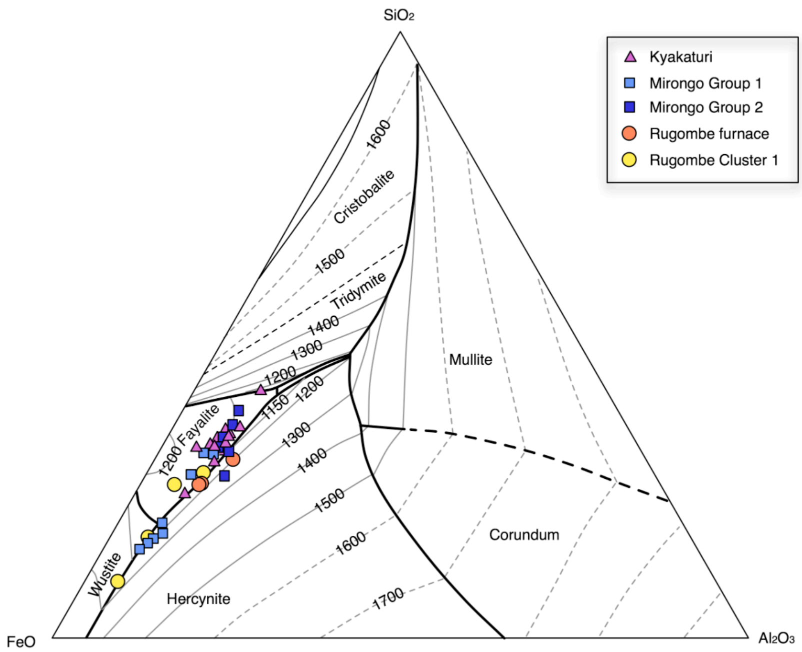


Figure 5.105 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO , with plots for all slag samples from Kyakaturi, Mirongo and Rugombe in terms of Al_2O_3+TiO_2 – SiO_2 – FeO+CaO+MnO (phase diagram adapted from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%

To examine further any potential relationships between the sites, the major components of all slag samples were plotted on a ternary diagram (Figure 5.105) in terms of (Al_2O_3, TiO_2)-(SiO_2)-(FeO, MnO, CaO). The samples from Kyakaturi group quite closely together, but the samples from Rugombe and Mirongo cover a wider range, reflecting the greater variability within these sample sets. However, not only do these two sites encompass a greater degree of variation within themselves, there is also some intriguing overlap between the sites. The samples from Mirongo Group 1 and the Rugombe cluster group closely together, as do the samples from Mirongo Group 2 and the Rugombe furnace. These were the samples that shared similarities in levels of manganese oxide, but to explore whether these groupings extended when all compounds were factored in, the samples from the three sites were also considered using principal component analysis (Figure 5.106, and Appendix M).

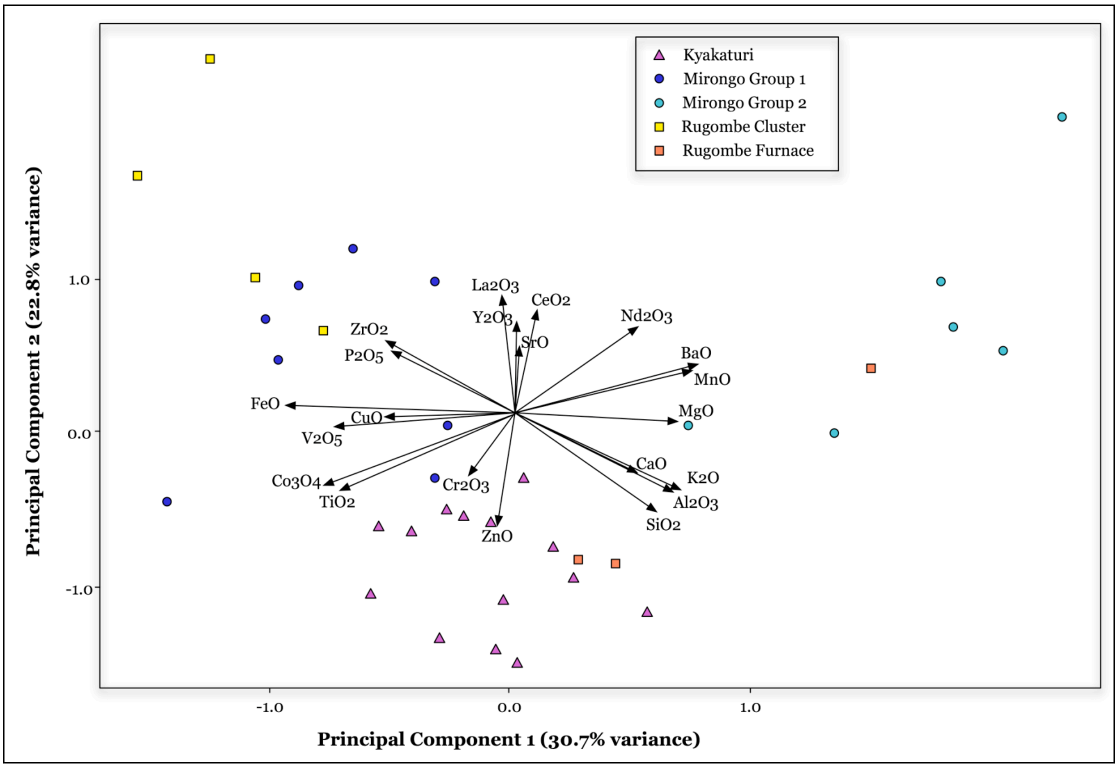


Figure 5.106 Graph of all early Mwenge slag samples in principal component space (PC1 vs. PC2)

Once again, the samples from Mirongo Group 1 and the Rugombe cluster group loosely together, to the left of the diagram; those from Mirongo Group 2 and the Rugombe furnace group to the right. However, although suggestive, these groupings are far from tight, and cannot be used to suggest a technological link between the two sites; rather just that there are similarities in the final slag compositions. The samples from Kyakaturi form a much more coherent group towards the bottom of the diagram.

In order to compare the refractory qualities of all the clays used in these technologies, the levels of alumina and titania of each technical ceramic sample, which increase the refractoriness of the clay, were plotted against the alkali, earth alkali metal and iron oxides, which lower it (Figure 5.107).

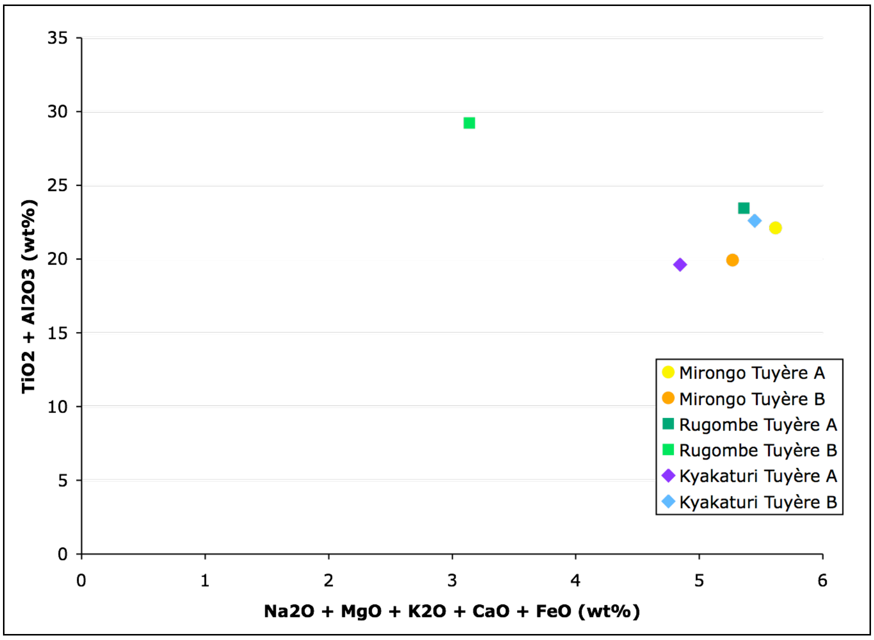


Figure 5.107 Scatter plot showing relative thermal refractoriness of tuyère samples from the sites discussed in this chapter. All figures are calculated from normalised PED-XRF data

All samples except for Rugombe Tuyère B – which appears the most refractory – group closely together. These tuyères are all made from kaolinitic clays typified by high alumina contents; bulk alumina contents range between 18wt% and 28wt% (averaging 21.5wt%). However, there is variable dilution with quartz in these ceramics. One interesting continuity between the sites is the use of grog temper in the tuyères, even if grog temper is not necessarily present in the accompanying domestic pottery samples that were analysed (although grog temper is evident in the domestic pottery samples from Rugombe).

The furnace remains were also very similar between sites, most especially regarding the sites of Mirongo and Rugombe (compare Figures 5.32 and 5.70) – sites only a few kilometres apart, and which also share slag compositional similarities. Not only were they broadly similar in size and shape, both bore a strange 'lip' on one side of the furnace – in Mirongo on the northern edge, and in Rugombe on the southern edge. It is difficult to suggest what this feature is indicative of, or what it may have resulted from, but it is interesting that it is present in both furnaces. However, one suggestion is that it may have been a tuyère port. If this were the case, this would indicate the use of only one tuyère at both of these sites. The use of a single, bellows-driven tuyère to smelt would probably restrict the maximum diameter of the furnace (*cf.* Rehder 2000: Chapter 9): both of these furnaces are small in comparison with that at Kyakaturi. The density of tuyère remains was also much higher at Kyakaturi than at either Rugombe or Mirongo. These ideas will be discussed in more depth in Chapter 7.

The relatively early radiocarbon dates for these sites have illustrated that it is difficult to predict the age of a site in this region on the basis of stylistic attributes of surface-collected pottery. Unfortunately this means that it is unclear as to how many of the ironworking sites that were encountered during the survey are attributable to this time period, and therefore it is not possible to begin to build a full picture of the scale of iron production at this time. However, it is evident from the results presented in this chapter that there are both parallels and variables in the iron production technologies at this time. The wider implications of this will be discussed in more detail in Chapters 7 and 8.

CHAPTER 6

TECHNOLOGICAL RECONSTRUCTIONS MWENGE, KINGDOM PERIOD

The remaining three excavated central Mwenge sites to be considered here were radiocarbon dated to post-seventeenth century AD. Unfortunately, due to fluctuations in the calibration curve during the period of these dates, they could not be further refined; as such we have to be content with contextualising them broadly as falling within the fully formed Nyoro kingdom. Descriptions of these sites will be presented in this chapter, accompanied by the analytical results relating to these sites. Their geographical locations are indicated on the map below (Figure 6.1).

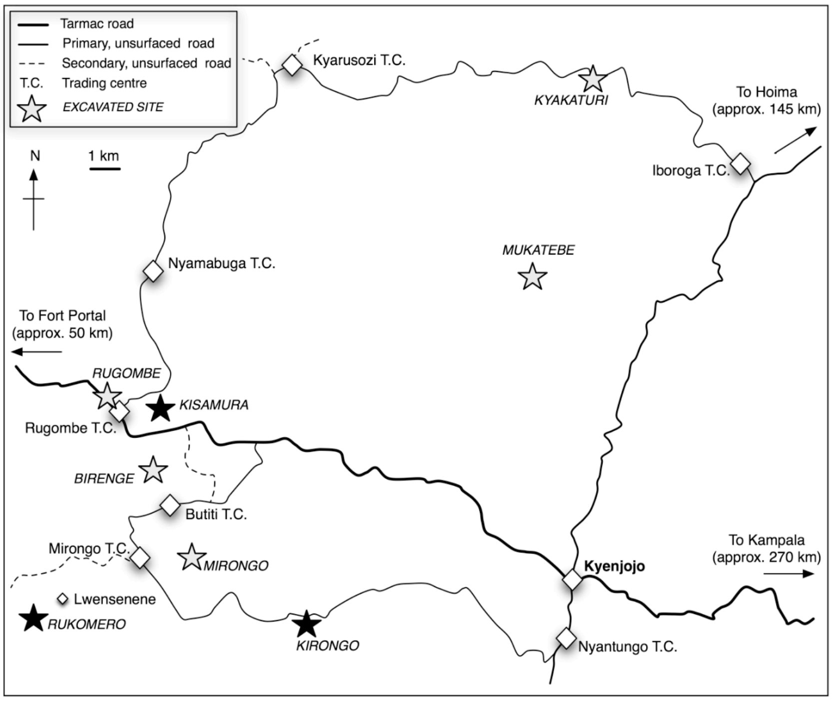


Figure 6.1 Map locating all excavated Mwenge sites in relation to major towns and roads. Sites discussed in this and the following chapter are marked with stars; those to be discussed in this chapter are marked with filled stars

PART ONE: KIRONGO (KRG)

between 17th and 20th centuries (1667-1949 cal. AD)

SITE DESCRIPTION

The small junction town of Kirongo (marked 'Rwekunga' on the Department of Lands and Surveys 1:50000 map 57/3) is situated midway along the Mirongo-Nyantungo road, under the jurisdiction of Nyantungo sub-county. It lies approximately 9km due west of Nyantungo trading centre. To the north, the topography rises steeply to join the ridge of the rocky and scarcely populated Isandara hills, which preside over the surrounding landscape. To the southeast, the terrain falls away more gently, with watercourses (including Nakinazi, which flows from the south of Kirongo) draining into the marsh basins of Wayiririrwe and Nyabaganga.

The archaeometallurgical remains that were to be excavated – slag clusters and a furnace base eroding from swept land in front of a house – were found in a compound at the foot of Kirongo Hill, on the south side of the main gravel road (KYS 15). A large number of smelting and mining sites were also found nearby: several on the southern slopes of the Isandara Hills (KYS22, 23, 24, 25, 26); one approximately one kilometre from Kirongo, to the southwest of Rwekunga Hill (KYS27). However, the remains at Kirongo were not limited to those in this one compound, and iron mining pits were also located only 100m away (KYS16). This mining site comprised seven *enambo* over an area of approximately 50m^2, mostly filled in. One was unusual in its shape however, comprising a narrow trench measuring approximately 20m long, sloping down the hillside. According to our informant, it was very deep when he was a child, but had since been partially filled in. Further mining pits were also said to exist on Kirongo Hill itself.

Between the mining site (KYS16) and the furnace site (KYS15) were two further large piles of slag blocks within an overgrown compound (KYS120), each covering an area of between 4 and 5m^2, and up to a height above the ground of approximately half a metre. Slag blocks had also been used within the house foundations and as markers for nearby flowerbeds (Figures 6.2 and 6.3). We were hoping to excavate at this site, in conjunction with KYS15, but were denied permission by the landowner for a number of reasons (primarily the proximity of the slag piles to a family grave) and we respected these wishes. However, we were able to briefly sketch and record the slag piles, and estimated that there were probably up to 100 slag blocks there, which were similar in external morphology to those in the neighbouring compound of KYS15.

Figure 6.2 House at KYS120, with slag being used in foundations

Figure 6.3 Detail of house in Figure 6.2, showing use of slag in foundations, KYS120

EXCAVATIONS

As mentioned, the remains that we were to investigate at Kirongo were more limited than we had hoped, as we were restricted to working with the archaeological remains within the single, original compound that we had found (KYS15). Here, a single furnace pit was found, along with two clusters of slag blocks in the family's banana plantations (Figure 6.4).

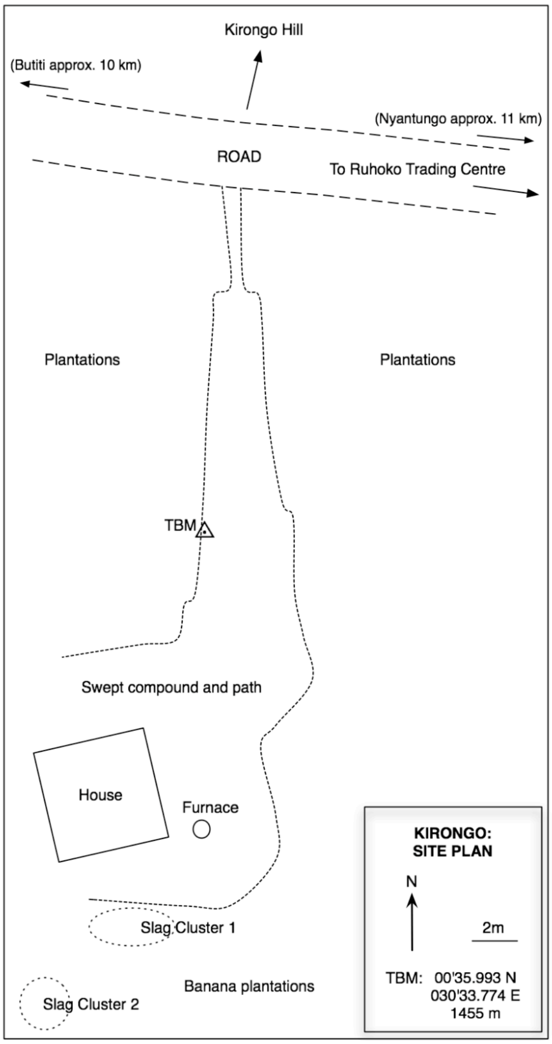


Figure 6.4 Site plan of Kirongo

The furnace base was faintly visible in the compound floor, and had originally been missed during the initial survey. However, once the compound floor had been trowelled back, the furnace – and the top of the slag block it contained – became more prominently visible (Figure 6.5).

Figure 6.5 Kirongo furnace, pre-excavation

Figure 6.6 In-situ slag block, Kirongo

Figure 6.7 In-situ slag block, Kirongo furnace, looking south

The furnace was excavated to reveal a single, in-situ slag block (Figures 6.6 and 6.7), which was fully recorded separately. This slag block was situated within a homogeneous, friable, ashy fill, with frequent charcoal inclusions (087), which was sealed beneath a thin (1-5cm) compacted layer of red, clayey deposit (086), probably hill wash (Figure 6.8). The charcoal fragments in context (087) included some examples of what looked like inflorescences or 'brushes'. These were similar in form to those seen on *Cyperaceae* species (e.g. papyrus), but their stems were not triangular in profile. The plant impressions that were preserved on the slag blocks at this site will be discussed later in this chapter.

In addition to the single large slag block, 1.5kg of slag fragments were also collected from the furnace fill. No tuyère fragments were recovered, but several fragments of what were assumed to be unreduced ore were also excavated from this context.

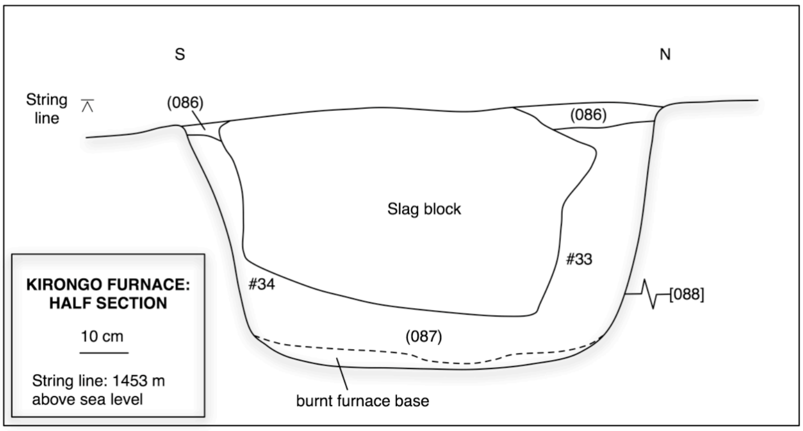


Figure 6.8 Composite profile of half-sectioned furnace at Kirongo, with in-situ slag block

Upon excavation of the furnace, the loose, dark furnace fill came down onto red, clay natural, except for under the slag block, which after its removal revealed the remains of a furnace base that was hardened and charred through exposure to high temperatures (Figure 6.9). Once recorded, the base of the furnace was dug through in order to ensure there were no further remains beneath it. The fully excavated furnace pit measured approximately 50cm in diameter and 30cm in depth, with near vertical sides and a slightly concave base once the burnt furnace base had been removed.

Figure 6.9 Kirongo furnace, fully excavated (prior to burnt furnace base removal)

A fragment of charcoal that had been recovered from beneath the single slag block (*cf.* Figure 6.8, #34) generated a radiocarbon date of 148 ±25 BP, which calibrates to 1667-1949 cal. AD with a probability of 95.3% (OxCal 4.1; IntCal09; Bronk Ramsey 2009; Reimer *et al.* 2009).

Concurrently with the excavation of the furnace base, the two clusters of slag blocks (indicated on Figure 6.4) were recorded and sampled from, as at previous sites. These clusters were relatively small, and were the result of clearing the land surrounding the compound during agriculture, rather than piles of slag refuse that had grown during a period of smelting. Eleven slag blocks from Cluster 1 (situated at the border between the swept compound and the surrounding banana plantation) were described and recorded in detail, many of which shared morphological similarities with that excavated from the furnace. Further into the banana plantation was a third, smaller, pile of slag blocks. Three of these were also recorded. The recorded slag blocks will be discussed further in the following chapter. No excavation other than the furnace base was undertaken at this site.

ANALYTICAL RESULTS AND INTERPRETATION

TECHNICAL CERAMIC ANALYSES

No tuyères were excavated from Kirongo, or collected from the surrounding area, and as such, it was not possible to carry out analyses on such samples. The lack of tuyères present at the site is not necessarily indicative that they weren't employed in the local smelting technologies; talking to local people in various regions of Mwenge throughout the survey, it became clear that tuyère and other pottery waste were frequently re-used as grog temper in new ceramics. This is perhaps highlighted by the presence of grog temper in many of the ceramic samples presented so far.

Nevertheless, five fragments of domestic pottery were collected from the road above the site (also recorded as survey site KYS15, though approximately 25m to the north of the smelting remains). These were all surface finds, collected during the initial survey of the site and its surroundings. One was decorated with twisted string roulette decoration, two with knotted strip roulette decoration and two showed no decoration. The two undecorated samples (Figures 6.10 and 6.11) were prepared for analysis using PED-XRF and optical microscopy. Although these samples were not necessarily related to the smelting remains, it was worth examining them in this way to provide some assessment, albeit limited, of the (presumably) local clay sources. A fragment of furnace wall was also analysed using PED-XRF.

Figure 6.10 Pot A, Kirongo

Figure 6.11 Pot B, Kirongo

Pot B (Figure 6.11) had originally been thought to be a small fragment of a tuyère, but on further examination it was unfortunately considered to have derived from a domestic pottery item.

Macroscopically, both samples seemed relatively coarse, with a high proportion of medium-sized inclusions, mostly grog, but also quartz. Pot A also appeared to have some mica within the clay, giving it a slightly glittery effect. On examination microscopically, these observations were confirmed (Figures 6.12 and 6.13). Bright crystals were also noted in both samples. Although these samples were not examined using SEM-EDS, it is likely these crystals are zircon, which would also explain the elevated levels of zirconia in the bulk chemical analyses (see Table 6.1).

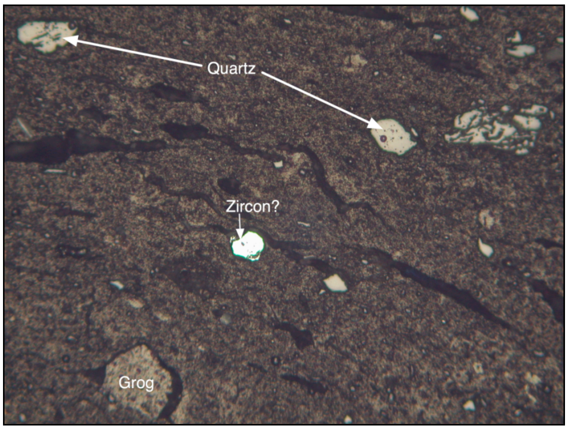


Figure 6.12 Photomicrograph of Pot A, Kirongo. Image width ≈ 2mm; PPL

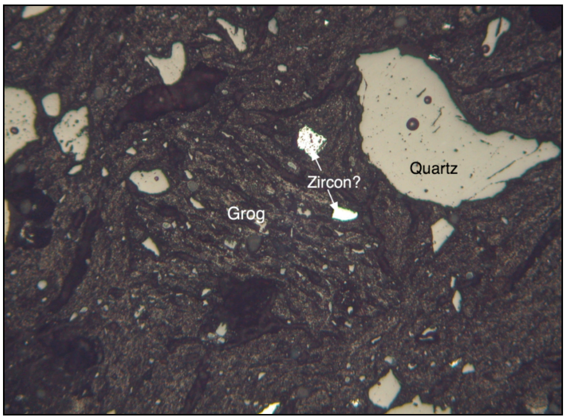


Figure 6.13 Photomicrograph of Pot B, Kirongo. Image width ≈ 2mm; PPL

The quartz inclusions in Pot A were much more regular in size than in Pot B, as well as being slightly less frequent. Again, this is reflected in the bulk chemical analyses of these samples; Pot A has a silica content of 64wt% whereas the silica content of Pot B is marginally higher at 69wt% (Table 6.1). Overall, however, the compositions of the two pottery samples were very similar (Table 6.1 and Figures 6.14 and 6.15).

KIRONGO (KRG)	Na$_2$O wt%	MgO wt%	Al$_2$O$_3$ wt%	*SiO$_2$ wt%*	SiO$_2$ wt%	P$_2$O$_5$ wt%	S wt%	K$_2$O wt%	CaO wt%	TiO$_2$ wt%	V$_2$O$_5$ wt%	Cr$_2$O$_3$ wt%	MnO wt%	FeO wt%
	Major and minor compounds													
				original	adjusted									
Cluster 1 Slag 1 M	0.28	0.28	5.99	*27.61*	25.96	0.89	0.06	1.00	2.09	0.17	0.03	0.10	6.32	54.60
Cluster 1 Slag 2 M	0.35	0.13	7.07	*20.96*	17.40	1.64	0.11	1.08	1.40	/	/	0.15	8.27	57.01
Cluster 1 Slag 4 M	0.30	0.29	8.39	*25.62*	22.93	1.40	0.10	1.06	2.89	/	/	0.11	9.43	47.94
Cluster 1 Slag 5 M	0.27	0.29	7.50	*28.73*	27.15	1.27	0.14	1.69	3.20	/	/	0.08	7.38	46.91
Cluster 1 Slag 6 M	0.42	0.11	9.04	*26.42*	23.91	1.95	0.07	1.20	2.15	≤0.11	/	0.07	9.05	48.15
Cluster 1 Slag 7 M	0.21	0.11	9.62	*23.30*	20.04	2.17	0.10	0.96	1.59	/	/	0.09	8.88	51.56
Cluster 1 Slag 9 M	0.33	0.17	6.61	*24.79*	21.82	1.14	0.09	1.18	1.36	0.16	0.01	0.15	6.62	55.96
Cluster 2 Slag 1 M	0.22	0.22	7.87	*21.32*	17.69	1.10	0.07	1.17	2.07	/	/	0.12	11.53	51.99
Cluster 2 Slag 2 T	0.25	0.58	9.87	*30.07*	29.46	1.24	0.10	1.98	3.06	/	/	0.09	8.23	43.01
Cluster 2 Slag 3 M	0.30	0.47	11.39	*27.63*	25.56	1.00	0.08	1.27	3.10	/	/	0.15	9.45	42.93
Furnace Slag C	0.26	0.25	7.56	*30.02*	29.42	1.17	0.09	1.88	3.50	0.31	/	0.04	7.19	46.20
Furnace Slag T	0.31	0.34	7.96	*26.09*	23.48	1.05	0.08	1.45	3.15	0.29	/	0.12	7.28	50.61
Furnace Slag M	0.33	0.30	6.81	*27.80*	25.86	1.13	0.08	1.64	3.32	0.28	/	0.05	7.39	49.53
Furnace Slag B	0.33	0.41	7.05	*26.72*	24.32	0.91	0.08	1.46	3.24	0.28	/	0.07	7.40	50.92
KYS120 Slag A	0.33	0.38	7.55	*31.08*	30.77	1.00	0.06	1.55	2.51	0.37	/	0.07	7.18	46.31
KYS120 Slag B	0.32	0.22	7.38	*30.81*	30.19	0.78	0.06	1.38	2.79	/	/	0.11	7.90	46.34
Ore (from furnace)	/	0.57	2.56	*3.04*	2.04	/	0.03	0.03	0.01	5.63	/	0.06	11.59	76.32
Pot A	≤0.33	0.25	28.78	*64.08*	64.08	0.01	0.05	0.45	0.30	1.45	0.03	0.02	0.02	4.15
Pot B	≤0.32	0.31	23.46	*69.20*	69.20	0.07	0.05	0.59	0.40	1.65	0.02	0.02	0.04	3.87
Furnace Wall	0.31	0.23	27.09	*58.29*	58.29	0.11	0.06	0.71	0.09	1.36	0.01	0.02	0.13	11.33

KIRONGO (KRG)	Co$_3$O$_4$ ppm	NiO ppm	CuO ppm	ZnO ppm	SrO ppm	Y$_2$O$_3$ ppm	ZrO$_2$ ppm	BaO ppm	La$_2$O$_3$ ppm	CeO$_2$ ppm	Nd$_2$O$_3$ ppm	Analytical total (wt%)
	Trace compounds											
Cluster 1 Slag 1 M	/	/	222	/	277	54	588	3574	317	458	274	109.77
Cluster 1 Slag 2 M	/	/	244	/	221	83	649	14878	456	921	953	112.24
Cluster 1 Slag 4 M	/	/	173	/	338	79	686	19726	321	2291	1074	109.26
Cluster 1 Slag 5 M	/	/	142	/	416	101	997	21006	336	1233	1221	109.14
Cluster 1 Slag 6 M	/	/	91	/	355	125	675	9906	320	1143	627	110.14
Cluster 1 Slag 7 M	/	/	177	/	712	121	900	10663	237	621	659	108.30
Cluster 1 Slag 9 M	/	/	175	/	189	70	481	11360	278	993	764	109.10
Cluster 2 Slag 1 M	/	/	364	/	417	70	445	20000	89	929	953	112.95
Cluster 2 Slag 2 T	/	/	221	/	258	75	679	12901	92	389	677	109.42
Cluster 2 Slag 3 M	/	/	159	/	299	95	570	18426	157	1457	1048	108.99
Furnace Slag C	/	/	247	/	487	114	692	11352	499	1195	790	111.50
Furnace Slag T	/	/	261	/	421	95	579	9129	395	1022	627	109.66
Furnace Slag M	/	/	260	/	440	100	609	9754	430	1102	676	111.36
Furnace Slag B	/	/	185	/	383	92	564	8233	370	863	569	111.08
KYS120 Slag A	/	/	89	/	260	74	569	13285	220	540	801	109.15
KYS120 Slag B	/	/	134	/	261	81	524	15492	566	958	965	108.61
Ore (from furnace)	/	347	/	612	/	/	≤77	551	/	/	/	97.14
Pot A	72	/	88	74	70	/	513	466	132	221	155	87.20
Pot B	61	/	57	74	79	/	924	397	254	353	190	93.11
Furnace Wall	232	/	70	91	26	/	928	541	179	369	≤91	88.04

Table 6.1 PED-XRF compositional data for all samples from Kirongo, normalised to 100%. All values are the average of the three analyses of each sample reported in Appendix N. 'Analytical total' shows the analytical total prior to normalisation. In this and following compositional tables, 'C' indicates crown sample

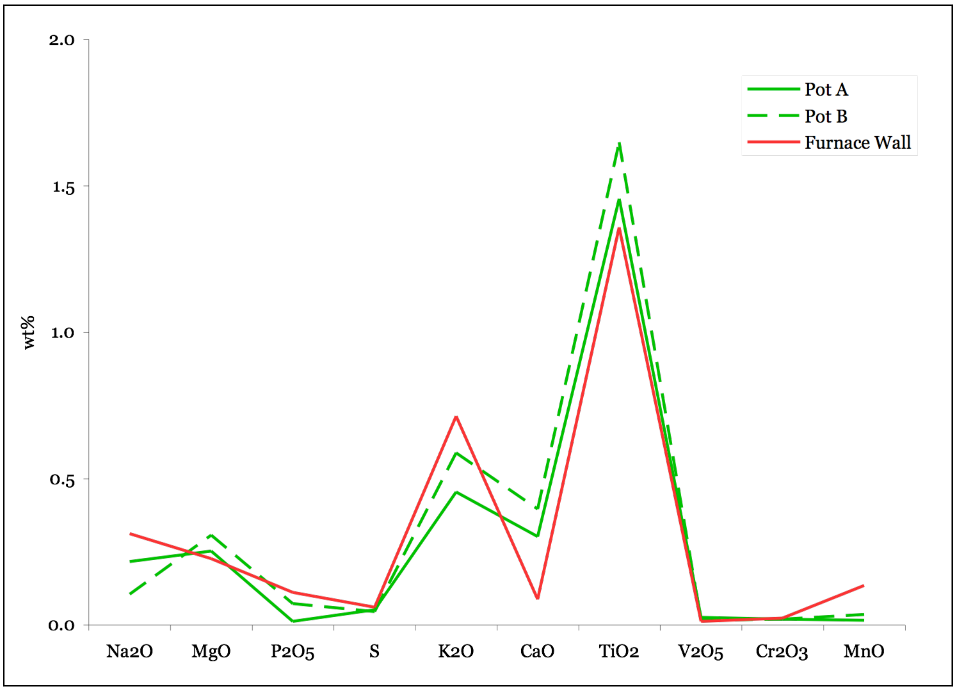


Figure 6.14 Line plot showing major and minor compounds (less Al_2O_3, SiO_2, FeO) of all analysed ceramics from Kirongo, calculated from PED-XRF data normalised to 100%

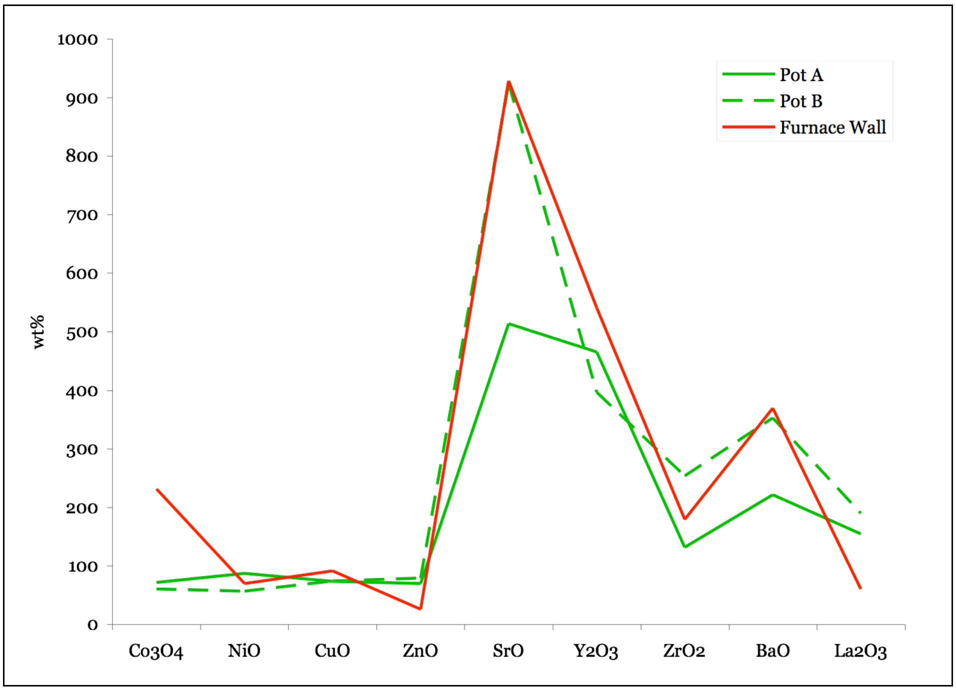


Figure 6.15 Line plot showing trace compounds of all analysed ceramics from Kirongo, calculated from PED-XRF data normalised to 100%

The sample of furnace wall that was analysed was also very similar in composition to these samples, though not as similar as the two pot samples were to each other, being notably different in lime, iron oxide, cobalt oxide and neodymium oxide. As such, it is possible to suggest that these clays might be close in composition to those that were used to make the tuyères at this site (if indeed it is assumed that tuyères were used at all in this production system). The alumina contents of all these ceramics are very high, ranging between 23 and 29wt%, with alumina to silica ratios of approximately 1:2 or 1:2.5. This taken in conjunction with the reasonably low iron oxide contents (c. 4wt%) and the low lime levels (c. >0.5wt%) means that the fabrics of these ceramics would have been suitably refractory to withstand the high temperatures of a furnace (in a system where the tuyères were not intended to contribute to the melt). Unfortunately however, not much more can be deduced without physical examples of the tuyères used.

METALLURGICAL ANALYSES

MACRO-DESCRIPTIONS

Two small clusters of slag blocks were found around the area of the furnace at Kirongo (*cf.* Figure 6.4), and it was from here and from the furnace that slag was sampled for this site. These slag blocks tended to be a dark bluish grey in colour, with several showing patches of a more greenish colouring, similar to that seen at Kyakaturi (Chapter 5, Part One). All appeared to be furnace slag from iron smelting that had not been tapped from a furnace; that is to say, they were devoid of any morphological features (slag flows etc.) that might suggest otherwise.

		Complete	Width a	Width b	Depth	Weight	Samples				
Cluster	Slag #	block?	cms	cms	cms	kg	Top	Middle	Bottom	ED-XRF	OM/SEM-EDS
1	1	N	31	30	29	20	✔	✔	✔	✔	
	2	N	31	29	18	19	✔	✔	✔	✔	
	3	Y	43	29	13	22	✔	✔	✔		
	4	Y	34	16	12	18	✔	✔	✔	✔	
	5	N	32	22	15	21	✔	✔	✔	✔	
	6	N	14	21	14	11		✔		✔	✔
	7	N	12	16	10	4		✔		✔	
	8	N	17	22	13	5		✔			
	9	N	15	15	15	6		✔		✔	
	10	N	14	14	16	4		✔			
	11	N	18	12	12	5		✔			
2	1	N	27	25	20	22	✔	✔	✔	✔	
	2	Y	25	33	30	21	✔		✔	✔	✔
	3	Y	30	24	20	19	✔	✔		✔	
Furnace	1	Y	32	22	43	45	✔	✔	✔	✔	✔

Table 6.2 Summary of macroscopic information recorded for the slag blocks from Kirongo

Although many of the slag blocks from Cluster 1 were broken, the dimensions and shapes of the original blocks were often clear; most of them derived from circular or ovoid slag blocks similar in appearance to the furnace slag. Many of these, when cut with a tile cutter for sample preparation, were crisscrossed with lines of metallic iron and bore lots of iron droplets plainly visible to the naked eye, as well as being exceptionally rich in charcoal fragments. The block uncovered from the furnace itself was typical of a single slag block formed within a pit-furnace. It was roughly oval in plan, with a base that had formed pressed against the furnace bottom. The patches of green colour were restricted to the base of the block. The upper surface showed greater levels of orange iron corrosion, and had the circular ridge of texturing that is indicative of the area where the bloom formed, which in this case measured 20cm in diameter. Four samples were taken from this block: one from this corroded upper area of bloom removal, one from the top of the slag block, one from the centre and one from the greenish base. All four of the samples were analysed using PED-XRF (*cf.* Table 6.2), in order to assess the level of chemical variation that occurred within that single smelt; two were also analysed using SEM-EDS (the upper bloom (crown) sample and the middle sample).

The slag blocks from Cluster 2 were slightly bluer in colour, and were more cone-shape in profile, with a large circular upper portion tapering down to almost a point. In this way they had some similarities with the slag blocks from Kisamura Cluster B, which will be presented later in this chapter (Part Two).

All of the slag blocks from Kirongo bore some impressions of small to medium reeds and grasses, although not nearly as frequently as at other sites. Whether this is due to a more restricted use of plants, or to the viscosity of the slag being unfavourable to the formation of plant impressions is difficult to say. However, the plant impressions were more common towards the bottom of the slag blocks. All samples were also of a high density. The slag from the furnace, arguably the slag that was most likely to be entirely complete, was the heaviest example from this site, weighing approximately 45kg. Other slag blocks varied in weight largely depending on how fragmented they were.

Two slag samples were also collected from KYS120 by the survey team, and were also prepared for analysis by PED-XRF (and one of them for additional microscopy and SEM-EDS analysis). Unfortunately, as these samples were collected following survey procedures rather than the recording systems implemented for excavation, there are no individual recording sheets for these blocks; because of this, comparable information regarding the original dimensions of these samples is not available. They were however, very similar in appearance to other slag samples from the site of Kirongo (Figure 6.16), and my lab notes for the reduced sample indicate that they were silvery-grey in colour, slightly less dense than the other samples from the main site, but very charcoal rich when cut.

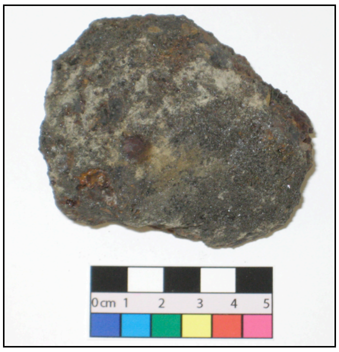


Figure 6.16 Slag sample from KYS120, as prepared in the field for shipping to UCL Institute of Archaeology

Two fragments of unreduced ore were excavated from the furnace pit, both weighing approximately 10g. These were very hard, black and dense, and were crystalline and 'sparkly' (Figure 6.17). In addition to the slag samples, one of these was also analysed using PED-XRF, optical microscopy and SEM-EDS.

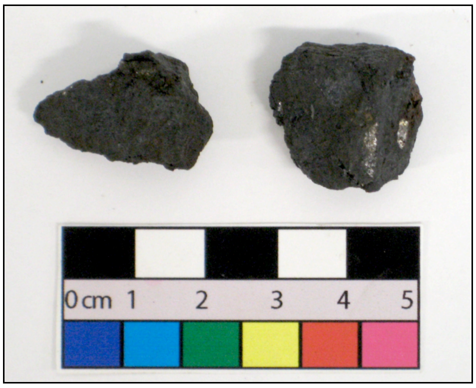


Figure 6.17 Fragments of possible ore excavated from furnace pit at Kirongo

ANALYSIS

The analysed ore sample revealed a bulk FeO[1] content of approximately 76wt%, 6wt% titania and 12wt% manganese oxide[2] (*cf.* Table 6.1 and Appendix N). Microscopically, large platy mineral inclusions with a bluish colour were seen to criss-cross the sample (Figure 6.18). SEM-EDS analysis showed that these bluish inclusions were primarily composed of titania (c. 55wt%) and manganese oxide (c. 40wt%), with some iron oxide and potash also present. The remaining ore matrix was primarily 78wt% FeO with significant manganese oxide and titania contributions (Table 6.3).

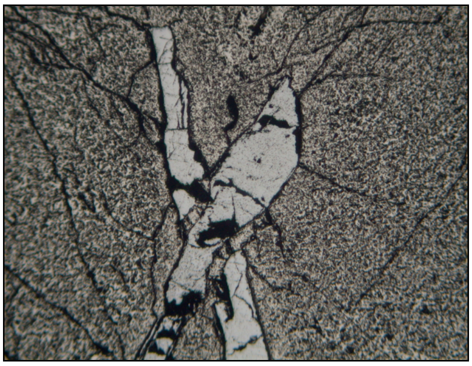


Figure 6.18 Photomicrograph of ore sample from Kirongo showing lathes of bluish titania-rich inclusions. Image width ≈ 2mm; PPL

KIRONGO (KRG)	MgO	Al2O3	TiO2	MnO	FeO
Ore matrix	0.8	1.2	3.0	16.9	78.2

Table 6.3 SEM-EDS compositional data for Kirongo ore (average of nine spot analyses)

The PED-XRF results of the slag analyses, shown in Table 6.1 and reported in full in Appendix N, show again that the samples were typical for bloomery slag. Iron oxide levels were relatively low across the sample set, averaging at 49wt% within a relatively narrow range between 43wt% and 57wt%. Silica contents averaged at 25wt% (with a CV of 17%), whereas alumina averaged at 8wt% (with a CV of 17%). The silica to alumina ratio averaged at 1:3 across all slag samples.

[1] The black colour and metallic lustre suggest that this is magnetite (Fe_3O_4), but in order to facilitate comparison with the slag samples (and the mass balance calculations later in the chapter) Fe^{Ox} is reported as FeO^{tot}.

[2] Again, likely to be significantly underestimated.

Variation within the three major components – alumina, silica and iron oxide – is therefore particularly low. However, variation within other compounds was also fairly low, with only titania and vanadium oxide having a CV of over 50%; these are the only compounds that are present in some samples and below detection limits in others. The coefficients of variation are presented visually in the graph below (Figure 6.19).

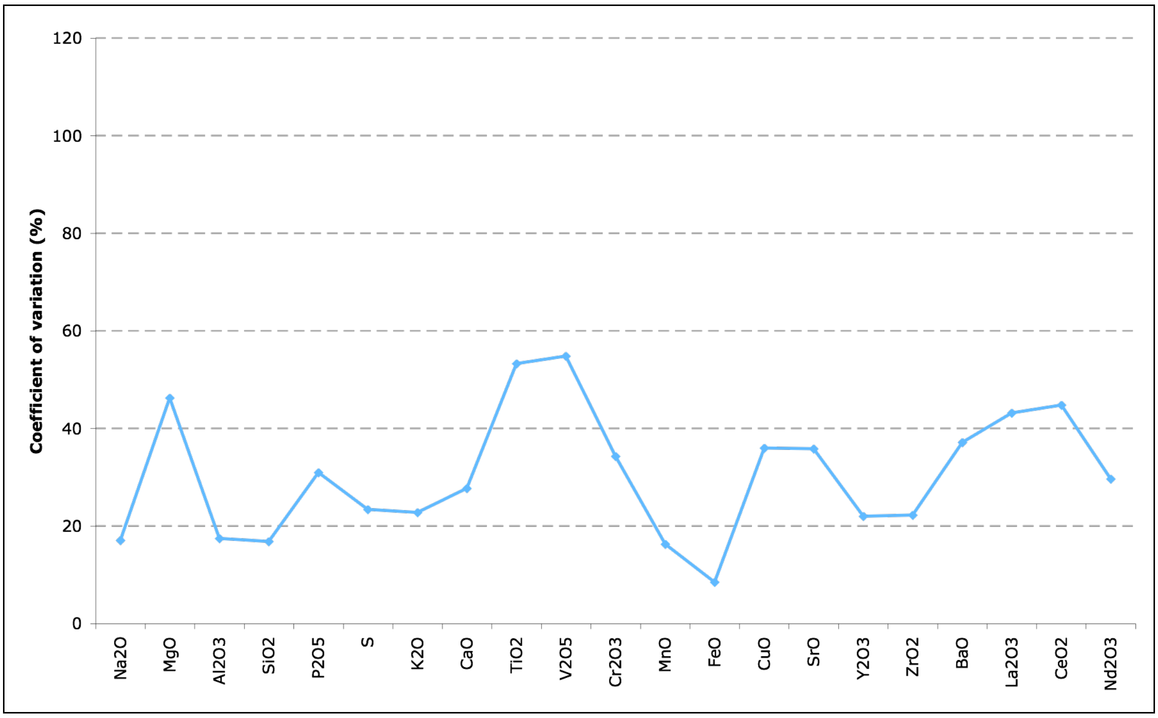


Figure 6.19 Coefficients of variation for all compounds in the sampled slag blocks from Kirongo, calculated from PED-XRF data normalised to 100%

Vanadium oxide is only present in two slag block samples from Cluster 1 – Cluster 1 Slag 1 Middle (C1S1M) and C1S9M. Titania, however, is present in three slag blocks from Cluster 1 – C1S1M, C1S6M, C1S9M – and the slag block from the furnace (FS). Taking into account the considerable level of titania in the analysed ore sample (c. 6wt%, *cf.* Table 6.1), it is perhaps surprising that there is not more titania present in the slag samples, particularly the furnace slag samples which are directly associated with it. A magnetite ore with an ilmenitic component used in pastoralist smelting in Laikipia, Kenya had a similar titania content (c. 7wt%), yet resulted in slag with titania contents of up to 12wt% (Iles and Martinón-Torres 2009). In the furnace slag at Kirongo, titania levels average at around 0.3wt%. This may be indicative that either the sample that was analysed was not representative of the ore selected for these smelts, or that, perhaps, this ore was combined with another with a lower titania content – perhaps in a similar fashion to that suggested at Mirongo Group 2 (*cf.* Chapter 6, Part Two). This line of enquiry will be pursued below in the discussion section.

Interestingly, the phosphate present in the slag (which averages at 1.24wt% across all the slag samples) also does not seem attributable to the ore that was sampled, where phosphate levels are below the detection limits. Levels of phosphate in the ceramics are also not high enough to explain the presence of phosphate in the slag. Once again, the presence of phosphate in the system is likely to have had a perceptible effect on the iron resulting from these smelts (*cf.* Chapter 5, Part One). This might suggest that a second ore (or a different ore) was involved in these smelts (*cf.* Table 6.1). However, there are suggestions, mentioned previously, that fuel ash can account for elevated phosphate levels (Schmidt 1997: 126), and this will be explored in more detail later.

Several differences were present between the different clusters. For example, levels of lanthanum oxide are lower in samples from Cluster 2; levels of manganese oxide were slightly higher in Cluster 2; titania was absent from all the samples from Cluster 2. However, when factor analysis was applied to these results, no overall distinct groupings of variation were apparent within this site. Perhaps this highlights minor variations in raw materials over time (e.g. the use of different parts of ore bodies) rather than indicating significant changes in technology or approach.

As with many of the sites from this region, whether early or late, manganese oxide is also present in relatively high concentrations across all samples, averaging 8wt% – levels that are as high as the alumina readings. This is consistent with the considerable manganese oxide present in the ore (approximately 12wt%).

Once again, barium was very high, reaching up to around 2wt% – too high to have derived exclusively from the fuel ash. However, judging from the large amount of charcoal from the cutting stage of sample preparation, fuel ash contribution is likely to be significant anyway, somewhat indicated by relatively high levels of fuel ash compounds (Mg, P, S, K, Ca, Sr; *cf.* Charlton *et al.* 2010). Nevertheless, barium oxide was present in relatively high concentrations in both the ore sample and the ceramics from this site; it is therefore likely that these sources are making a contribution to the slag formation within this technology. On applying factor analysis to the data (*cf.* Appendix O), the only strong correlation apparent with barium oxide is Nd_2O_3, with a correlation factor of 0.96 (the value for the MnO-BaO correlation is 0.61).

In conjunction with the variation *between* smelts, a further observation is the particularly low level of variation that is present within the single slag block that had multiple samples taken from it (FS1, Figure 6.20). Only one compound – magnesia – showed variation above 20%. This low level of variation is unlike that seen at previous sites – presumably fairly constant parameters were maintained over the course of this single smelting episode – and is especially noteworthy considering that a sample of corroded crown was included in the calculations. This, coupled with the low variation between smelts (*cf.* Figure 6.19), is perhaps an indication that the smelters at Kirongo had a level of control and regulation over their smelts that exceeded that seen at the sites presented in the previous chapter.

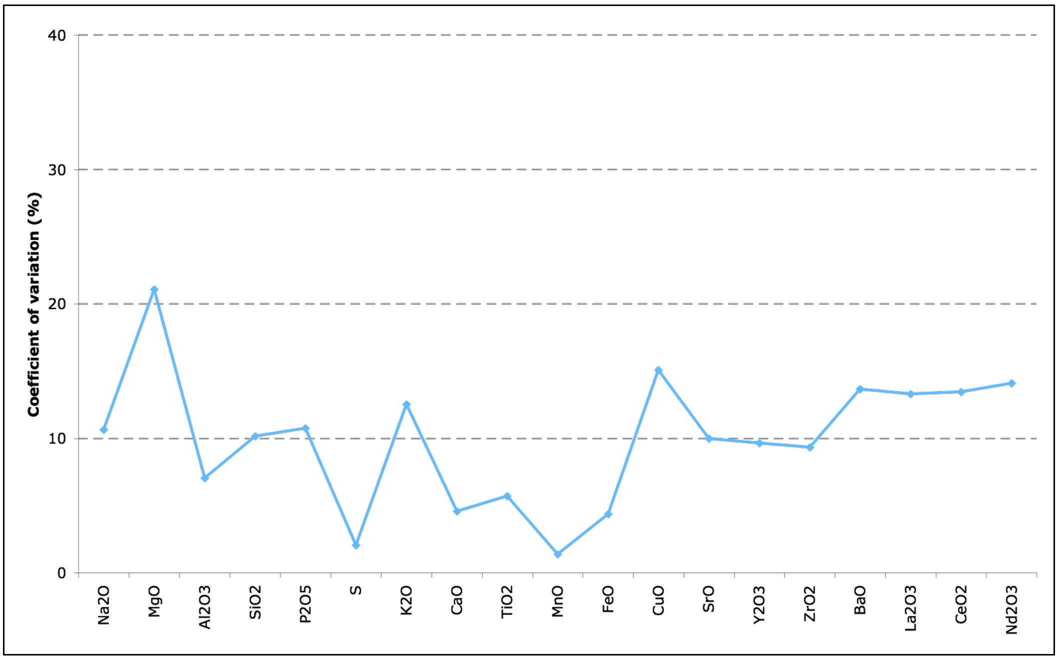


Figure 6.20 Coefficients of variation for all compounds through start-middle-end of smelt, calculated from four samples from the Kirongo furnace slag

Microscopically, the slag samples as a set were also quite similar, and were homogeneous throughout individual samples. They tended to be very porous (*cf.* Figure 6.21), and many showed signs of corrosion and degradation of certain phases (*cf.* Figures 6.23, 6.27 and 6.28). With the exception of C1S2M, all samples were dominated by olivines (approximately 90area%), with very little wüstite present, ranging from 1 to 7area% (Figures 6.21 and 6.22), consistent with the low iron oxide reading in the bulk analysis. In many cases, the only wüstite present was exsolving from the glassy matrix (Figure 6.23). The olivine phases were blocky in all samples, yet the crystal sizes were relatively small – this is likely to indicate a moderate cooling rate. Correspondingly, there was very little glassy matrix.

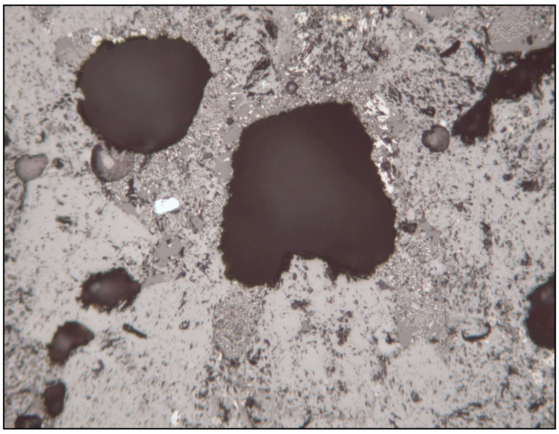


Figure 6.21 Photomicrograph of sample C1S5M, Kirongo, showing porosity (black) and blocky olivines (mid grey). Image width ≈ 2mm; PPL

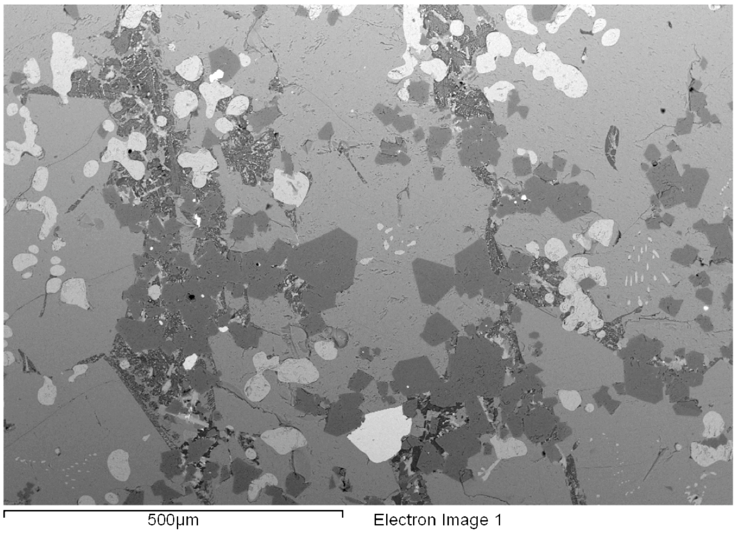


Figure 6.22 BSE image of C1S6M, Kirongo, showing blocky olivines (mid grey), magnetitic-hercynite (dark grey), wüstite (light grey) and leucitic matrix (darkest grey)

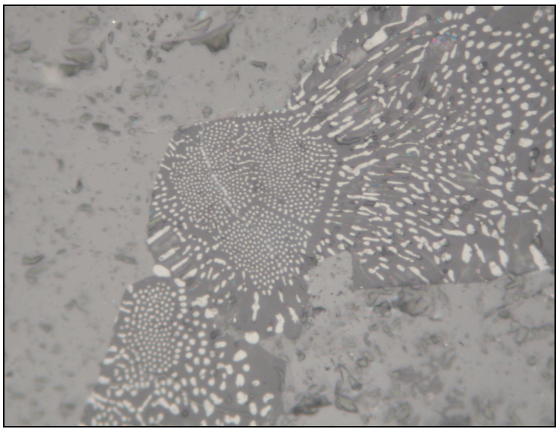


Figure 6.23 Photomicrograph of sample C1S5M, Kirongo showing eutectic wüstite in a leucitic matrix. Image width ≈ 0.2mm; PPL

Microanalysis revealed that there was significant substitution for iron oxide in what were presumed to be the fayalitic phases. Manganese oxide contributed between 15 and 25wt% across all analysed samples, making it the Mn-rich olivine, knebelite; lime was also present at between 1 and 4wt%. The spot analyses of knebelite from the middle sample of the furnace slag showed a particularly wide range of lime contributions, which averaged at 4wt% but ranged between 1 and 14wt%. The wüstite of these samples also appeared to contain additional metal oxides, with titania often present at between 1 and 3wt%, and manganese oxide present at between 5 and 10wt%. The glassy matrix was found to be approaching the composition of leucite in all samples, with some contributions of phosphate (1-3wt%), iron oxide (1-10wt%), lime (1-2wt%), manganese oxide (c. 1wt%) and barium oxide (2-5wt%).

In most samples, small euhedral crystals were also apparent – pinkish in the optical microscopy and dark in the SEM backscattered electron imaging (Figures 6.22 and 6.24), yet these tended to be rare within samples, often comprising <1area% of the sample surfaces though rising to 5area% in one sample (C1S6M). These were identified through the SEM-EDS analyses to comprise approximately 40wt% alumina and 50wt% iron oxide, corresponding with magnetitic-hercynite.

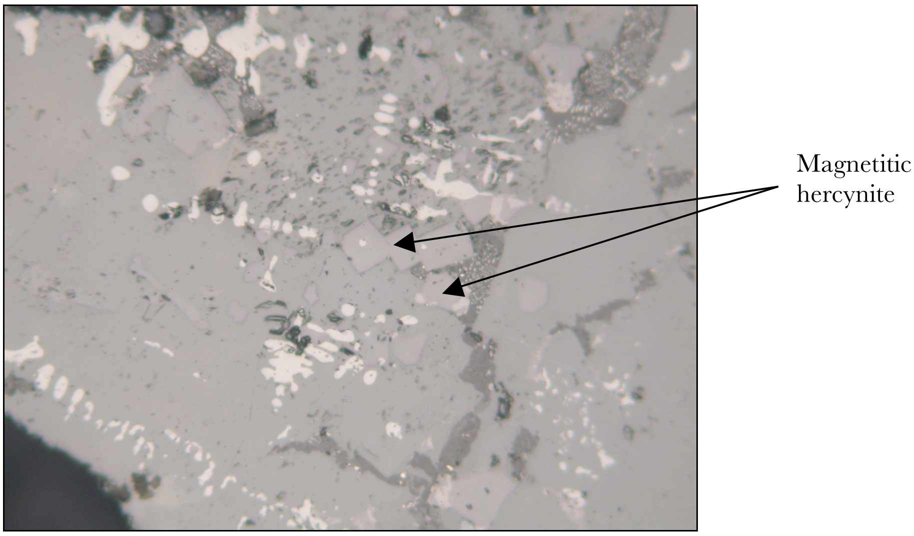


Figure 6.24 Sample FS1C B, Kirongo, showing dendritic wüstite (light grey), blocky knebelite (mid grey), and leucitic matrix (dark grey). Black in bottom left hand corner is porosity; magnetitic-hercynite is indicated separately. Image width ≈ 1mm; PPL

The sample analysed by microscopy from KYS120 was also very similar to the other samples from Kirongo (Figure 6.25), and this ties in with the similar bulk chemical analyses of these samples. This porous yet homogeneous sample was dominated by approximately 90area% knebelite, which was very blocky in form and which again had significant levels of manganese oxide (c. 17wt%) and lime (c. 1-2wt%). Leucitic glassy matrix comprised nearly 5area% of the sample, and the only wüstite present was that exsolving from the matrix (<1area%). Spot analysis of wüstite suggested that it contained up to 1wt% copper oxide. The rest of the sample was made up of limited proportions of small hercynitic phases (with some substitution of manganese oxide and titania) and accretions of iron metal (Figure 6.26).

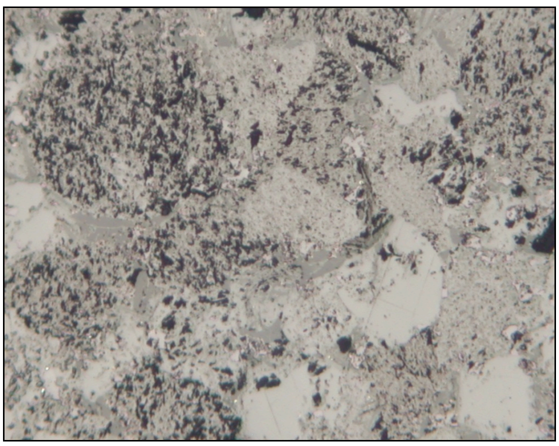


Figure 6.25 Photomicrograph of sample KYS120, showing blocky knebelite. Image width ≈ 1mm; PPL

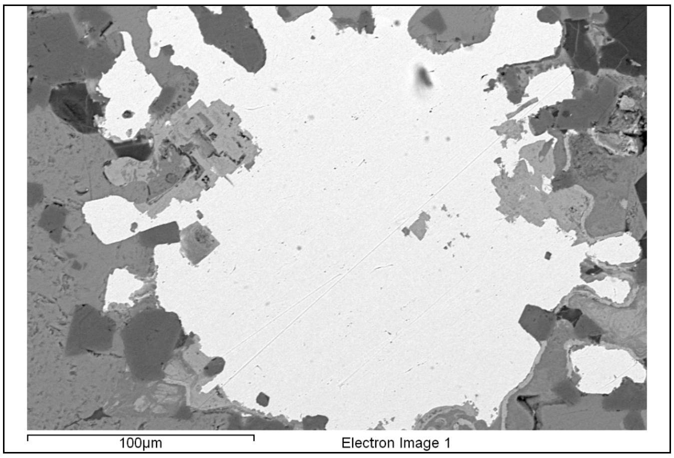


Figure 6.26 BSE image of KYS120, showing accumulation of iron metal (white)

The sample from Cluster 1, Slag 2 was much more heavily dominated by wüstite than the other samples examined microscopically, some reduced in part to foils of metallic iron (Figure 6.27), and this is reflected in the higher bulk iron oxide for this sample (c. 57wt%). However, the rest of the phases were very similar to other samples, including the small angular phases, which were still present in this sample (see Figure 6.27, towards the centre of the image).

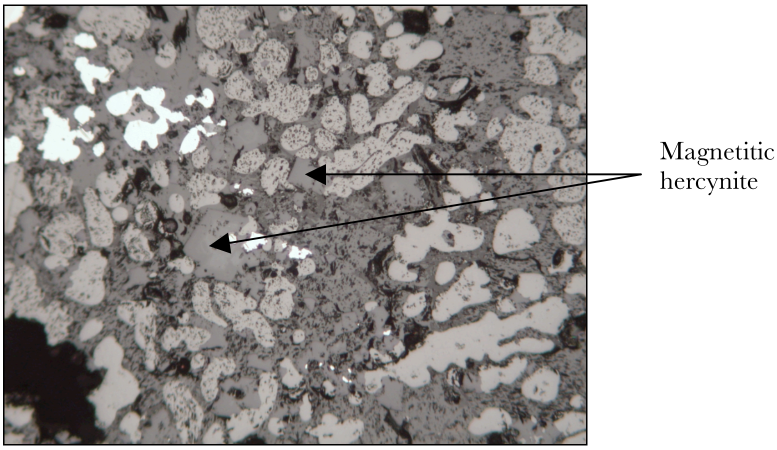


Figure 6.27 Photomicrograph of sample C1S2M, Kirongo, showing globular wüstite (mid grey), blocky knebelite (dark grey), iron (white) and porosity (black). Magnetitic-hercynite is indicated separately. Image width ≈ 1mm; PPL

The uppermost sample from the furnace slag appeared different to the other samples, consistent with the fact that it was formed at the end of the smelt, closest to the bloom. It was very porous, and was criss-crossed with foils of bluish corroded iron (Figure 6.27). This sample was also dominated by olivines (presumably, once again, knebelite), but this phase was present in a more skeletal form than in other samples from this site (and in the other samples from this slag block), which is indicative of a faster cooling time for this region of the slag block. Considering that it formed within a unique environment at the top of the slag block, and that it would be exposed to cooler air when the bloom was removed, this would be a logical observation. In the two samples from the furnace slag, darker phases were present with higher lime contents of up to 47wt%. This is in agreement with the higher lime levels overall in these furnace slag samples (*cf.* Table 6.1).

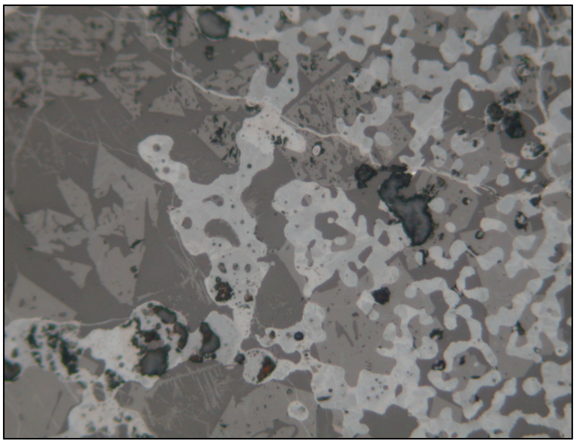


Figure 6.28 Sample FS1C A, Kirongo, showing skeletal knebelite (mid grey, to the left of the image), leucitic matrix (dark grey), and corroded iron foils (bluish grey). Image width ≈ 1mm; PPL

Of further interest was an unusual material noted towards the surface of this sample (Figure 6.29), possibly a remnant ore mineral. Upon SEM-EDS analysis, several area analyses gave an average composition of 83wt% iron oxide – a richer ore than that excavated from the furnace (*cf.* Table 6.1) – and it additionally contained significant contents of alumina and silica, as well as some lime and manganese oxide (Table 6.4). However, the analytical totals of the readings from this particle were comparatively low. Over the three area analyses taken, each comprising an area of approximately 30-40μm^2, the analytical totals averaged at about 65wt%. This might indicate that this inclusion is instead vegetal in nature, perhaps a fragment of charcoal, but its appearance does not readily suggest this. However, the fact that this sample originates from the very uppermost region of the slag block, somewhat strengthens this possibility.

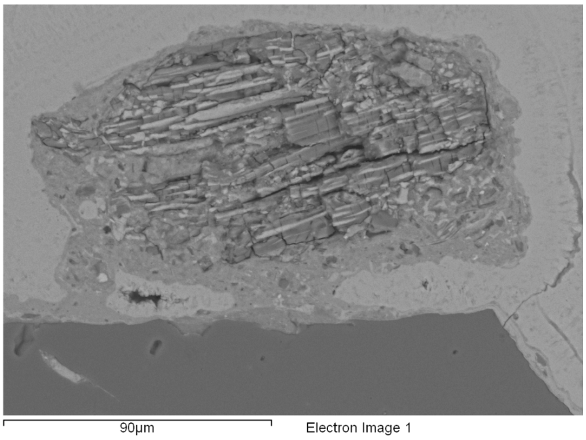


Figure 6.29 BSE image of possible relict grain of ore, FS1C A, Kirongo

	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	(wt%)
Ore?	5.0	7.9	0.5	2.9	1.2	83.0	

Table 6.4 Averaged SEM-EDS analytical results for possible fragment of ore shown in Figure 6.29, normalised to 100%

Several possible scenarios now present themselves as to the nature of the ore(s) used in the smelts at Kirongo, which will now be discussed in the section below.

DISCUSSION AND SUMMARY

Two trace compounds picked up in the PED-XRF analysis of the ore (nickel and zinc oxides), were absent from the slag samples. As outlined in Chapter 5, Part One, this is likely to be due to the more reactive metal (Zn) evaporating through the course of the smelt, and to the nickel partitioning to the iron metal, thereby remaining in the iron bloom rather than the slag.

However, several other inferences about the contributions to the melt can be made from the bulk chemical analyses generated from these samples. The low alumina levels in the analysed ore sample suggest that the alumina from the ceramics might have made a particularly high contribution to the smelt. Although no examples of tuyères were available to analyse, it was possible to propose a crude mass balance that does suggest that this system would be feasible (i.e. a smelting system utilising this ore and technical ceramics manufactured with clay and temper similar to that used in the local domestic pottery and furnace wall).

Several assumptions (further to those above) were necessary to formulate this scenario. Regarding the ore, a quarter will go into the bloom rather than the slag (i.e. from 100 units of 75% FeO ore, 25 units of FeO go to the bloom, leaving 50 units of FeO and 25 units of other compounds to go into the slag) – a yield of iron which seems reasonable compared with ethnographic and experimental reconstructions and other mass balance calculations (e.g. Cline 1937, Thompson and Young 1999, Charlton 2007). Taking these assumptions and presumptions into account, it does seem possible that an ore with these iron and alumina levels (not in conjunction with a second ore) *might* result in a slag broadly similar to those that are present at Kirongo (Table 6.5).

		Contributions to slag					
	Input	FeO	SiO_2	Al_2O_3	Others	Total in slag	Total in bloom
Ore (75% FeO)	100	50	2	3	20	75	25
Technical ceramics	unlimited	1.5	16	7	0.5	25	
Hypothetical slag		**51.5**	**18**	**10**	**20.5**	**100**	
Kirongo slag		***50***	***25***	***8***	***13***	***100***	

Table 6.5 Mass balance calculations for contributions to the smelts at Kirongo, utilising only the ore excavated from the furnace

Due to the low silica content of the ore[3], this hypothetical system forces a large proportion of the silica to come from the technical ceramics. Zirconia levels are very high in the ceramics from this site; presuming the technical ceramics (i.e. tuyères) were also high in this compound, this may explain the high levels in the slag even though there is not much in the ore. However, if ceramics are seen to be the primary contributor of alumina and silica to the system, it would be expected that the ratio of alumina to silica in the ceramic samples would match the ratio of alumina to silica in the slag samples. This was not the case, with alumina to silica ratios in the slag samples averaging 1:3.2 (ranging between 1:2.1 and 1:4.3), whereas in the ceramic samples they averaged at 1:2.4 (ranging between 1:2.2 and 1:2.9). This does however, not take into account the differences in quartz temper (and consequently silica levels)

[3] Although the silica content of the residual ore fragment presented in Figure 6.29 and Table 6.4 is marginally higher than that of the sample prepared for PED-XRF, this is only a small inclusion (<100μm) and is unlikely to be representative.

that have tended to be noted between samples of domestic pottery and samples of tuyère at other sites under examination; it is possible that the alumina to silica levels would be closer to those in the slag samples if greater quartz temper was used in the hypothetical tuyères at this site.

However, the chemical analysis of (non-technical) ceramics from this site highlighted their refractory nature; any technical ceramics at this site – if manufactured from similar clay resources – are likely to have been similarly refractory, and therefore presumably would not have made such a major contribution to the smelts. Nevertheless, as noted previously, there was a lot of charcoal visible in the slag during sample preparation, as well as metallic iron. This would perhaps suggest a relatively high fuel to ore ratio, and corresponding high temperatures. This would explain the contribution of technical ceramics to a certain extent, but still probably not as much as calculated in the previous mass balance. As such, it was re-modelled with an additional source of silica entering the system through the addition of a silica (i.e. quartz) flux (Table 6.6).

		Contributions to slag					
	Input	FeO	SiO_2	Al_2O_3	Others	Total in slag	Total in bloom
Ore (75% FeO)	100	50	2	3	20	75	25
Technical ceramics	unlimited	1	9.5	4	0.5	15	
Silica flux	unlimited		10			10	
Hypothetical slag		**51**	**21.5**	**7**	**20.5**	**100**	
Kirongo slag		***50***	***25***	***8***	***13***	***100***	

Table 6.6 Mass balance calculations for contributions to the smelts at Kirongo, utilising the ore excavated from the furnace and a silica flux

This is a more comfortable scenario (although there is no direct archaeological evidence to suggest a quartz flux was used at this site), yet it still does not come very close to matching the actual slag compositions at Kirongo. Phosphate levels were still not explained in these posited systems, nor were the seemingly diluted levels of titania. Copper, a metal present in all the slag samples was also absent from this sample of ore. As such, a second operating system was experimented with. As the possible ore fragment in sample FS12BlA also contained no phosphate, the results of the ore analysis from Kyakaturi (*cf.* Chapter 5, Table 5.1 and Figure 5.25) were used to model this scenario – an ore that was seen to have levels of phosphate that seemingly resulted in slag with comparable levels of phosphate as those at Kirongo (Table 6.7). Again, a silica flux had to be factored in, due to the lack of silica in both of these rich ores.

		Contributions to slag						
	Input	FeO	SiO_2	Al_2O_3	P_2O_5	Others	Total in slag	Total in bloom
Ore A (75% FeO)	50	23	1	2		10	35	15
Ore B (90% FeO)	50	29	2	2	1	2	35	15
Technical ceramics	unlimited	1	10	4		1	15	
Silica flux	unlimited		15				15	
Hypothetical slag		**53**	**28**	**8**	**1**	**13**	**100**	
Kirongo slag		***50***	***25***	***8***	***1***	***13***	***100***	

Table 6.7 Mass balance calculations for contributions to the smelts at Kirongo, using an additional hypothetical ore and a silica flux

This system does seem to result in hypothetical slag that is closer in composition to that of the actual Kirongo slag samples. A blend with an Mn-poor ore would also explain why MnO values are not enriched in the slag compared to the archaeological ore; a blending of ores may also account for the disparity in titania levels between the slag and the ore. Furthermore, as discussed previously, the elevated phosphate levels may be (at least in part) due to contributions from the fuel ash, especially in these manganese-enriched smelts. There are many more assumptions inherent in this system (the nature of the second ore, the contribution and yield of each, the use of a silica flux), and it still cannot explain all the compounds present in the slag that are likely to come from the ore. Barium oxide, present in particularly high quantities in the Kirongo slag, so high as to have some derivation from the ore, is absent from the ore analyses from Kirongo. Presumably, this compound may have come from the possible second ore (or indeed from an alternative primary ore), and serves as a reminder that as with all theoretical mass balances developed from excavated ore fragments, the relationship between these residual pieces and the actual ores used in the smelts is highly hypothetical.

Unfortunately (at least for this situation), ethnographic reconstructions have shown that smelting technologies can potentially combine a large number of different ores within a single smelt, for example Jane Humphris' reconstruction of iron smelting in southern Rwanda, where at least four different ores – three haematite and one magnetite – were used (Humphris 2010). This makes any reconstructions of the ores used in past smelts (through the analyses of slag remains and unreduced ores, that may or may not have been originally used), a challenging feat. All that can be assuredly said about the ingredients used in the Kirongo smelts, is that there is likely to have been a number of iron ores used, tuyères – although absent from the site – are likely to have made some contribution to the melt, and that if the ores themselves were indeed so rich, a silica flux would have been required to form a slag. One further notable contribution would have been fuel ash – especially given that the fuel to ore ratio is likely to have been high. This would have had additional consequences for the final compositions of the slag blocks that have not been considered here.

By plotting all the available samples onto a ternary phase diagram (Figure 6.30), further suggestions can be made as to the operation of the smelts at this site. The slag samples mainly straddle the low temperature trough between fayalite and hercynite, and most would have formed at temperatures of at least 1100-1200˚C. Several samples, those with higher alumina contents, fall deeper within the hercynitic region of the diagram, and consequently it is likely that the solidification temperatures of these slag blocks would have been higher, up to 1300˚C. It is possible that these slag blocks would have been more viscous (if actual operating temperatures were not considerably higher than for the other smelts), yet looking at the separate recording sheets for the individual slag blocks, it seems that this did not have a noticeable effect on the resulting slag morphology or the presence of plant impressions. C2S3M, the slag block with the highest alumina content, had the most prolific plant impressions visible on its surface; although this slag block was indeed irregular in morphology, others with alumina contents of over 9wt% (C1S6M, C1S7M, C2S2T) were well formed. Consequently, a relatively high operating temperature resulting in fluid slags can be assumed.

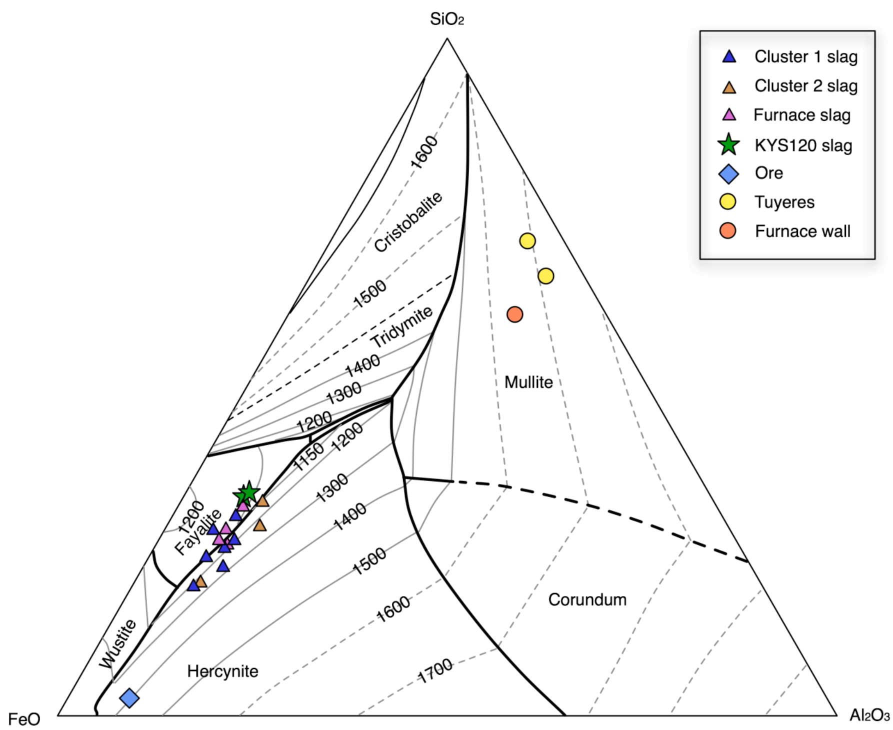


Figure 6.30 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO, with plots for all samples from Kirongo (phase diagram adapted from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%; slag samples are plotted in terms of $Al_2O_3+TiO_2$ – SiO_2 – FeO+MnO+CaO

To summarise, the slag blocks that resulted from the smelting undertaken at Kirongo in the later second millennium AD, were likely the outcome of what was probably a strictly controlled and repeatable smelting procedure. It is possible that multiple ores were used alongside technical ceramics (now absent from the site) that would have contributed silica and alumina to the smelting system. The low CVs within and between smelts are particularly remarkable if it is accepted that a range of ores and fluxes were mixed for every smelt, as such, a tight control can be supposed to have been garnered over these smelting events.

Part Two: Kisamura (KSM)

between 17th and 20th centuries (1684-1929 cal. AD)

Site Description

The small hamlet of Kisamura is located very close to the site of Rugombe, discussed in the previous chapter (Chapter 5, Part Three). Kisamura is, like Rugombe, located just off the tarmac road that links Kyenjojo to Fort Portal. A few kilometres past the turning to Butiti, the road crosses a number of small streams (that lead into the Katobire river and eventually into the Nyansimbi marsh); just to the north of these crossings, on the ridge of a steeply sided hill, sits Kisamura, overlooking the valleys and hills to the east and the south (Figure 6.31).

Figure 6.31 View to the east from half way up Kisamura hill

The archaeometallurgical site discussed here was first indicated by the heavily eroded remains of a furnace base sitting proud in the middle of the main path leading down to the tarmac road, just at the point at which the slope levelled out at the top of the hill (Figure 6.32). In addition to this, upon talking further to local residents, we were led to a number of clusters of slag blocks in various compounds across the hilltop.

The proximity to Rugombe meant that many of the iron ore sites mentioned in Chapter 5 were also very close to Kisamura, in particular Rugombe Kasozi, which lies only about 1km due west of Kisamura. The extensive mining sites of Birenge were also very close, about 2km south of Kisamura on the other side of the main road. Many sites consisting of slag scatters and slag piles were also nearby, a testament to the scale of iron production in this localised area in the past. As mentioned before, water was available nearby at the foot of the hill on which Kisamura stands, both from the Katobire watercourse to the south and east, and the Rutale to the north.

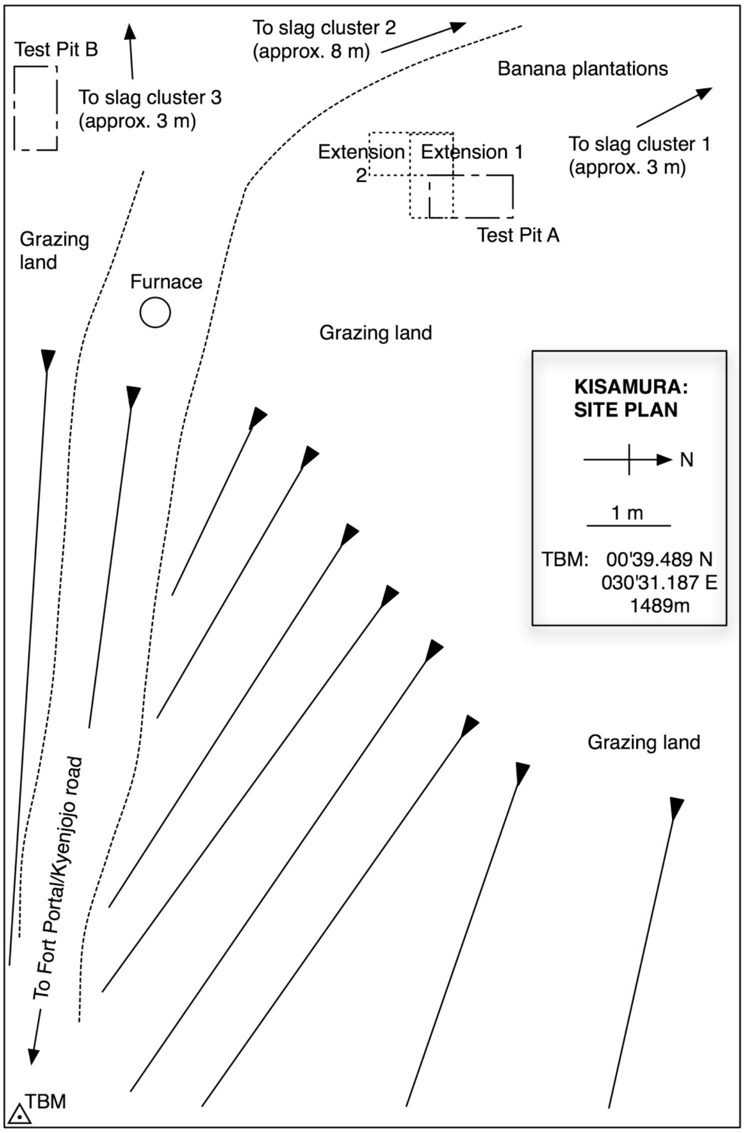


Figure 6.32 Site plan of Kisamura

EXCAVATIONS

The furnace base was the initial excavation to be undertaken at this site. Its location on a well-trodden path and at the top of a hillside meant that it had suffered a lot of erosion, both underfoot and from water action (Figure 6.33). After cleaning, it became clear that the remaining furnace pit was indeed very shallow (Figure 6.34).

Figure 6.33 Kisamura furnace, prior to excavation, looking west

Figure 6.34 Furnace at Kisamura, prior to excavation

As was to be expected, the upper centimetres were comprised of mixed, red clays that had washed over the furnace remains (Figure 6.35). Beneath this, however, and especially towards the western side of the furnace, which had been protected by remnants of furnace wall and slag blocks, a more typical furnace fill remained. This fill – a reddish brown silty clay – was between 7 and 12cm thick, and contained infrequent but substantial charcoal inclusions, one of which (sealed beneath a slag block) was taken for radiocarbon dating. The complete excavation revealed a very shallow oval hollow (1m by 70 cm), most likely the very base of what was once a much deeper furnace pit (Figure 6.36).

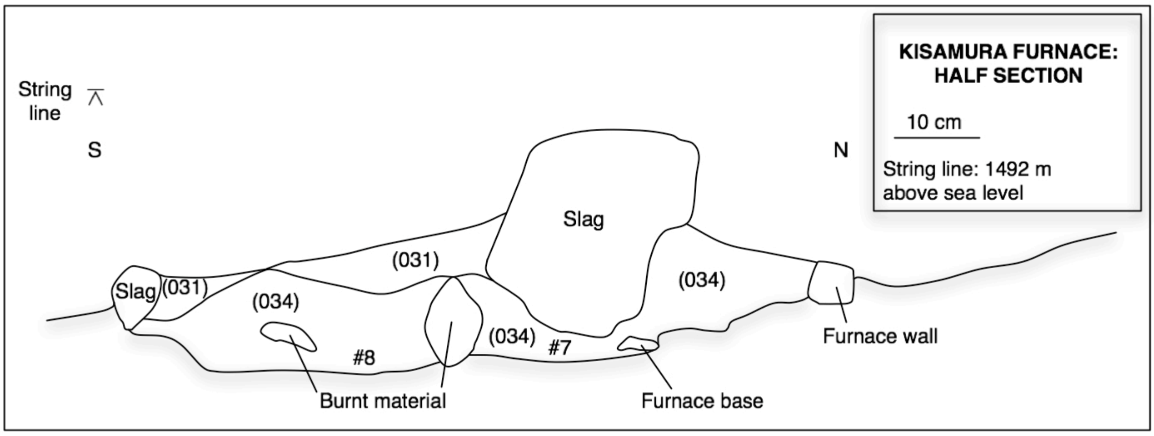


Figure 6.35 Composite profile of fully-excavated furnace at Kisamura

Figure 6.36 Furnace base at Kisamura remaining as a very shallow hollow. Fully excavated

What was particularly interesting about this furnace was the prominent presence of thick furnace wall, especially considering the shallow nature of the fully excavated pit. During excavation, it appeared that this furnace wall was remaining where it had fallen into the furnace (Figures 6.37, 6.38 and 6.39). This raised some suggestions that there may not have ever been a deep pit as seen in the other furnaces in the region covered by this these, rather that the furnace wall was built up from almost ground level. This practice has been seen in other regions of Great Lakes Africa, namely Burundi and Rwanda (*cf.* Raymaekers and van Noten 1986; Célis 1987: 100-101; Craddock *et al.* 2007). Alternatively, it is possible that instead there was a very thick furnace lining that was applied to extend the entire depth of the furnace pit, perhaps pre-formed 'bricks' that were intended also to build up a supra-surface furnace lining.

Figure 6.37 The western edge of the furnace at Kisamura, with fragments of furnace wall. Looking north

Figure 6.38 Detail of furnace wall fragment in-situ, Kisamura

Several – though not many – of these wall fragments showed deep, parallel impressions (*cf.* Figure 6.39), which indicate that at some point, whilst the clay remained plastic, these sections came into contact with large reeds. Nevertheless, it is unclear what the presence of these substantial fragments of furnace wall indicates with regards to the construction of the furnace. One possibility is that an inner cylinder was built of bent reeds and the clay was applied on top of this frame; Peter Crew builds furnaces this way (M. Martinón-Torres pers. comm. 2010).

Figure 6.39 Fragments of furnace wall, after removal from furnace, Kisamura

A sample of charcoal was recovered from underneath one of the large slag blocks in the furnace fill (*cf.* Figure 6.35, #7), and was sent for radiocarbon dating. The date that was returned was 102 ±25 BP, which calibrates to 1684-1929 cal. AD with a 95.4% probability (OxCal 4.1; IntCal09; Bronk Ramsey 2009; Reimer *et al.* 2009).

In terms of other finds, 200g of furnace wall were collected from the furnace, along with 25kg of slag (some showing distinctive papyrus impressions), and the occasional pottery sherd. No tuyère fragments were recovered from the furnace.

Much of the land surrounding the furnace was, at the time of the fieldwork, set aside for the grazing of goats rather than cultivation. This allowed us to open a number of testpits in this area whilst excavation of the furnace was taking place (*cf.* Figure 6.32). This began with Testpit A, a 1m by 2m trench that was located just a few metres to the northwest of the furnace. This testpit was excavated in 10cm spits until the edge of what turned out later to be a series of circular pits was uncovered in the southwest corner. At this discovery, the trench was extended, in the end twice, to investigate the nature and extent of this feature (Figure 6.40).

Figure 6.40 Testpit A, with two extensions, showing pits [035] (right, fully excavated) and [046] (left, partially excavated), Kisamura. (North is to the right of the image)

Finds were limited in number, both within the testpit as a whole, and in pits [035] and [046] that were uncovered, mainly comprising small fragments of undecorated pottery and small pieces of charcoal. However, on excavation of pit [046] a panga (machete) blade was revealed, which had seemingly been placed horizontally within the pit (Figures 6.41 and 6.42). This seemingly deliberate deposition of an iron object in an area so close to smelting remains is very interesting. Unfortunately however, no charcoal from the pit was present in a large enough fragment to be dated, nor was the panga brought back to the UK for analysis. However, considering the limited extent of rust and decay of the iron, it is unlikely to be very old, although no one who lived in the vicinity had memories of why such a deposition might take place. No other features were found in this testpit.

Figure 6.41 Panga blade excavated from context (038), Kisamura

Figure 6.42 Panga blade within partially excavated pit [046], Kisamura. Scale bar gradated every 10cm. (North is to the left of the image)

A second 1m by 2m testpit was also excavated to the south of the path where the furnace was located. This was also excavated in 10cm spits but no features were found in this trench. A lot of (mostly undecorated) pottery was excavated from this testpit, as well as some slag and tuyère fragments. A number of tuyère samples were retained for analysis in conjunction with the material excavated from the furnace and the slag blocks sampled from the clusters.

In addition to four large slag fragments that were excavated from the furnace, a number of slag blocks from clusters in the vicinity of the furnace were sampled. Three clusters were identified. The one with the largest number of slag blocks was the furthest from the furnace remains – Cluster 1. This cluster, and the others at this site, had been formed as part of field clearance to make way for agriculture. There were approximately fifteen large and unbroken slag blocks at Cluster 2, seven of which were recorded and sampled. Many shared distinctive morphological features, which will be discussed in the following chapter. Cluster 2 was much closer to the furnace, but contained far fewer slag blocks. Only three out of ten blocks were recorded, but these were very similar to those found in Cluster 1. At Cluster 3 – within the kitchen area of a house compound – there were only three slag blocks, but these appeared slightly different in morphology to the other slag blocks at this site. It was for this reason that two of these three slag blocks were chosen for recording and sampling.

ANALYTICAL RESULTS AND INTERPRETATION

TECHNICAL CERAMIC ANALYSES

Only a very limited number of tuyères were excavated from Kisamura, all of them from a single context – (040), the second 10cm spit beneath the topsoil in Testpit B. In total nine sherds were excavated (Figure 6.43, *cf.* Appendix P).

Figure 6.43 Tuyère fragments excavated from context (040), Testpit B, Kisamura

These tuyère fragments tended to derive from larger tuyères than those at other sites, with on average, thicker walls (c. 1.7cm, compared to an average of 1.1cm so far) and slightly larger internal diameters (c. 4.8cm compared to an average of 4.2cm). They were generally orangey or greyish brown in colour, and it was observed that most were tempered with a combination of quartz (often coarse) and grog. All showed some extent of vitrification. No sections of any flared ends were recovered, but the circular diameter of the tuyères from this site was obvious. The vitrified nature of the sherds meant that there were limited opportunities to examine the surfaces of the tuyères for any distinguishing marks of manufacture.

One sample of tuyère was selected – on the basis of it being a typical example from this site – for chemical and microscope analysis (Figure 6.44). Parallel striations were apparent on the inside surface of this tuyère fragment, suggesting that these tuyères were also formed around a central stick (Figure 6.45).

Figure 6.44 Tuyère from Kisamura selected for analysis (outer view)

Figure 6.45 Tuyère from Kisamura selected for analysis (inner view)

A piece of furnace wall was also selected for analysis (Figure 6.46). As can be seen from the photograph below, this furnace wall fragment was approximately 5cm thick, and was bright orange in colour and smooth on the outer edge.

Figure 6.46 Furnace wall fragment excavated from Kisamura furnace selected for analysis

Finally, a sherd of undecorated domestic pottery, excavated from the furnace, was also selected for analysis (Figure 6.47).

Figure 6.47 Domestic pottery sample from Kisamura furnace

Upon macroscopic inspection, the tuyère sample and the pot sample were seen to incorporate quartz inclusions, but in the pot sample these quartz inclusions seemed poorly sorted, as compared to the much more frequent and regular quartz inclusions in the tuyère sample. When examined microscopically, these observations were confirmed, suggesting that the quartz is more likely to be the result of a deliberate addition of temper in the tuyère sample (Figures 6.48 and 6.49). Grog inclusions were also apparent in both samples, although much less frequently in the tuyère sample (Figures 6.49 and 6.50).

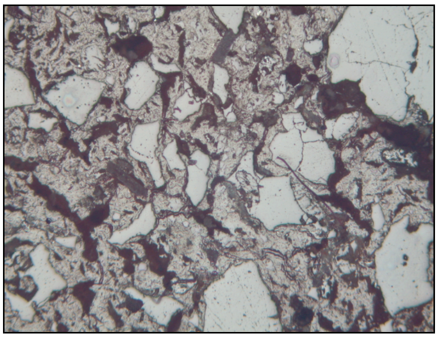


Figure 6.48 Quartz inclusions in tuyère sample, Kisamura. Image width ≈ 2mm; PPL

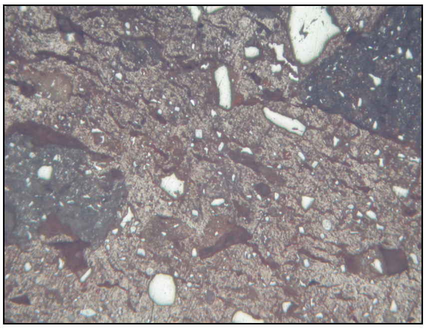


Figure 6.49 Domestic pottery sample, showing grog and quartz inclusions, Kisamura. Image width ≈ 2mm; PPL

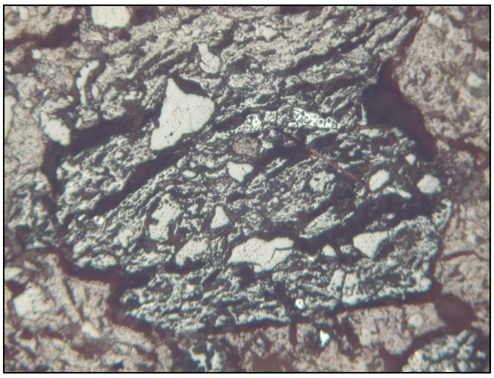


Figure 6.50 Grog inclusion in tuyère sample, Kisamura. Image width ≈ 2mm; PPL

In contrast to the uniform, linear porosity of the domestic pottery sample (*cf.* Figure 6.49), the tuyère sample had considerable coarse, angular porosity with random orientation (*cf.* Figure 6.48). This, taken into consideration alongside the presence of frequent voids in the polished surface of the sample where quartz grains had fallen out during sample preparation, reflects the coarse manufacture and low firing of this part of the tuyère. Nevertheless, the quartz inclusions and porosity would have in turn increased the resistance of such tuyères to the severe operating conditions within the furnace. Through similar observations, the pot also seemed relatively low fired.

The PED-XRF analyses, as shown below in Table 6.8, and reported in full in Appendix Q, show in fact the comparatively close compositional data regarding silica content of the tuyère (c. 71wt%) and domestic pottery (c. 67wt%) samples. As this contradicts what might be expected from the optical microscopy, principally regarding the higher quartz inclusion content of the tuyère sample, the bulk chemical results seem to suggest therefore that the clay used in the manufacture of the tuyère had a lower alumina to silica ratio than that in the domestic pottery. As it is, the resulting alumina to silica ratios of the two ceramics work out as very similar when read from the bulk chemical analysis, with both samples giving an approximate ratio of 1:3. Without the optical microscopy, this may have been misleading.

The sample of furnace wall shows a particularly high reading for iron oxide, which suggests that this sample had been contaminated due to its proximity to the smelt. However, on reduction of the iron oxide content to 4wt% followed by re-normalising the data, the alumina content comes out at 32wt% and the silica content at 55wt%, giving a hypothetical alumina to silica ratio of 1:1.7. An alternative might be that the furnace wall was tempered with slag. This might be backed up by the high concentration of zinc oxide in this sample (167ppm, compared to 48ppm in the tuyère) – a compound that is present in the slag from this site. Zinc oxide is reactive with silica, and would be attracted to ceramics in a furnace setting (Kearns *et al.* forthcoming). However, this zinc may also be indicative of contamination directly from the charge, and no crushed slag fragments were detected in a visual inspection of the furnace wall sample.

KISAMURA (KSM)	Major and minor compounds													
	Na_2O	MgO	Al_2O_3	*SiO_2*	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO
	wt%	wt%	wt%	*wt%*	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
				original	adjusted									
Cluster 1 Slag 1 M	≤0.29	0.28	6.28	*25.15*	22.26	1.48	0.11	2.26	1.47	/	0.01	0.10	8.06	53.53
Cluster 1 Slag 2 T	0.19	0.41	6.19	*22.33*	18.87	1.81	0.11	2.04	1.41	0.13	0.04	0.13	6.01	58.42
Cluster 1 Slag 3 M	0.29	0.38	5.30	*25.85*	23.26	1.57	0.08	1.75	1.94	0.10	0.02	0.09	7.12	54.74
Cluater 1 Slag 4 M	0.18	0.32	6.04	*24.04*	20.91	1.72	0.17	1.92	1.53	0.18	0.04	0.11	5.71	57.11
Cluster 1 Slag 5 M	0.25	0.30	7.20	*25.53*	22.85	1.71	0.23	2.83	1.18	0.18	0.06	0.11	5.13	54.46
Cluster 1 Slag 6 B	0.23	0.37	6.31	*21.15*	17.55	1.43	0.12	1.99	1.18	0.13	0.02	0.08	8.71	57.69
Cluster 1 Slag 6 C	≤0.18	0.31	8.05	*24.04*	20.92	2.09	0.16	2.54	1.62	0.08	≤0.01	0.09	7.78	52.07
Cluster 1 Slag 6 M	0.30	0.42	7.82	*24.60*	21.65	2.21	0.13	2.78	1.67	/	0.02	0.09	8.63	50.44
Cluster 1 Slag 6 T	0.31	0.36	7.01	*24.38*	21.33	2.10	0.14	2.56	1.60	/	0.02	0.12	7.97	52.53
Cluster 2 Slag 1 M	0.23	0.27	8.70	*23.92*	20.69	1.03	0.12	0.90	1.69	/	/	0.14	9.09	51.80
Cluster 2 Slag 2 M	0.28	0.26	8.26	*26.87*	24.72	1.47	0.10	1.12	1.98	/	/	0.08	12.17	44.46
Cluster 2 Slag 3 M	0.31	0.19	7.47	*28.76*	27.32	1.14	0.12	0.48	1.61	/	/	0.07	11.48	47.48
Cluster 3 Slag 1 M	0.35	0.23	8.67	*23.83*	20.97	2.02	0.20	1.08	1.94	/	/	0.10	9.50	50.57
Cluster 3 Slag 2 M	0.26	0.52	5.81	*27.54*	25.61	1.51	0.11	2.12	1.83	0.12	0.03	0.10	6.08	53.15
Furnace Slag 1 M	0.28	≤0.24	6.93	*23.33*	20.06	1.92	0.15	0.90	2.06	/	/	0.07	9.34	52.82
Ore A	0.18	0.01	6.57	*34.35*	34.35	0.61	0.06	0.27	0.04	0.13	0.05	0.52	0.25	56.75
Ore B	0.18	/	26.97	*21.59*	18.03	0.55	0.10	0.54	1.62	/	/	0.10	23.16	19.71
Ore C	0.33	/	1.13	*71.86*	71.86	/	0.02	0.00	0.02	0.03	0.01	0.01	0.07	26.43
Tuyère	0.22	0.19	23.31	*70.69*	70.69	/	0.03	1.86	0.12	1.02	0.01	0.01	0.03	2.39
Pot	0.37	0.47	23.75	*66.83*	66.83	0.06	0.05	1.11	0.51	1.32	0.02	0.03	0.03	5.27
Furnace Wall	0.23	0.73	26.84	*46.15*	46.15	0.99	0.11	1.22	1.02	1.87	0.05	0.03	0.37	20.14

KISAMURA (KSM)	Trace compounds													
	Co_3O_4	NiO	CuO	ZnO	SeO_2	Rb_2O	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Cluster 1 Slag 1 M	/	/	420	21	50	/	410	79	676	6447	960	853	723	113.78
Cluster 1 Slag 2 T	/	/	341	14	46	/	413	81	745	3545	879	925	529	113.29
Cluster 1 Slag 3 M	/	/	157	15	37	/	438	97	932	3300	1301	841	632	110.30
Cluater 1 Slag 4 M	/	/	271	16	85	/	354	67	855	5165	888	947	614	109.43
Cluster 1 Slag 5 M	/	/	186	13	102	/	229	53	656	4943	685	780	546	107.59
Cluster 1 Slag 6 B	/	/	357	8	≤23	/	273	82	499	3234	411	686	315	107.26
Cluster 1 Slag 6 C	/	/	266	22	62	/	470	129	769	5590	963	1459	747	105.02
Cluster 1 Slag 6 M	/	/	156	17	56	/	436	112	639	4897	749	1058	650	112.22
Cluster 1 Slag 6 T	/	/	200	11	50	/	425	113	658	4895	805	1269	642	111.90
Cluster 2 Slag 1 M	/	/	226	40	21	/	283	77	523	17086	449	995	1272	108.15
Cluster 2 Slag 2 M	/	/	253	34	/	/	342	141	993	23771	709	1340	1867	110.20
Cluster 2 Slag 3 M	/	/	168	41	27	/	406	126	772	5162	735	895	636	109.69
Cluster 3 Slag 1 M	/	/	533	50	47	/	751	174	901	9190	1002	1480	988	110.00
Cluster 3 Slag 2 M	/	/	214	20	63	/	370	86	837	4008	1106	883	663	109.14
Furnace Slag 1 M	/	/	466	22	40	/	686	138	1094	13926	1115	1494	1285	108.85
Ore A	559	/	362	79	/	/	215	16	141	205	275	250	39	103.82
Ore B	/	1370	1909	742	/	/	137	197	214	44216	864	1485	3581	84.41
Ore C	403	31	151	26	/	/	/	5	58	/	12	14	27	112.29
Tuyère	42	29	71	48	/	80	33	14	498	340	60	84	110	101.72
Pot	85	67	83	90	/	66	62	32	578	340	122	138	101	93.90
Furnace Wall	393	75	247	167	/	65	86	91	530	512	209	247	163	87.02

Table 6.8 PED-XRF compositional data for all samples from Kisamura, normalised to 100%. All values are the average of the three analyses of each sample reported in Appendix Q. 'Analytical total' shows the analytical total prior to normalisation

The previous suggestion that different clays were being used for these different ceramics is substantiated by the variation in the other compounds of these samples. This variation is demonstrated visually in Figures 6.51 and 6.52 below.

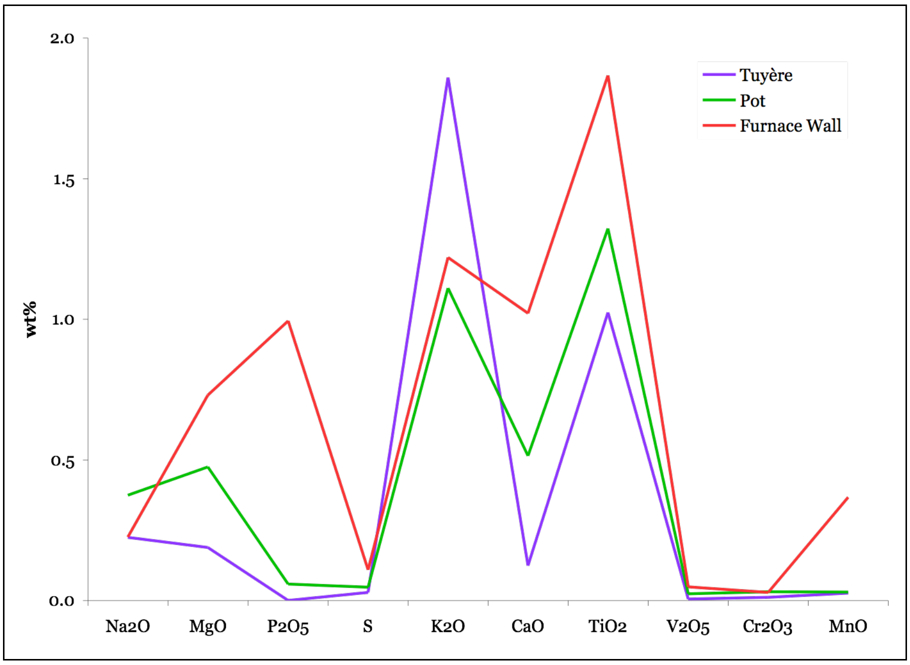


Figure 6.51 Line plot showing major and minor compounds (less Al_2O_3, SiO_2, FeO) of all analysed ceramics from Kisamura, calculated from PED-XRF data normalised to 100%

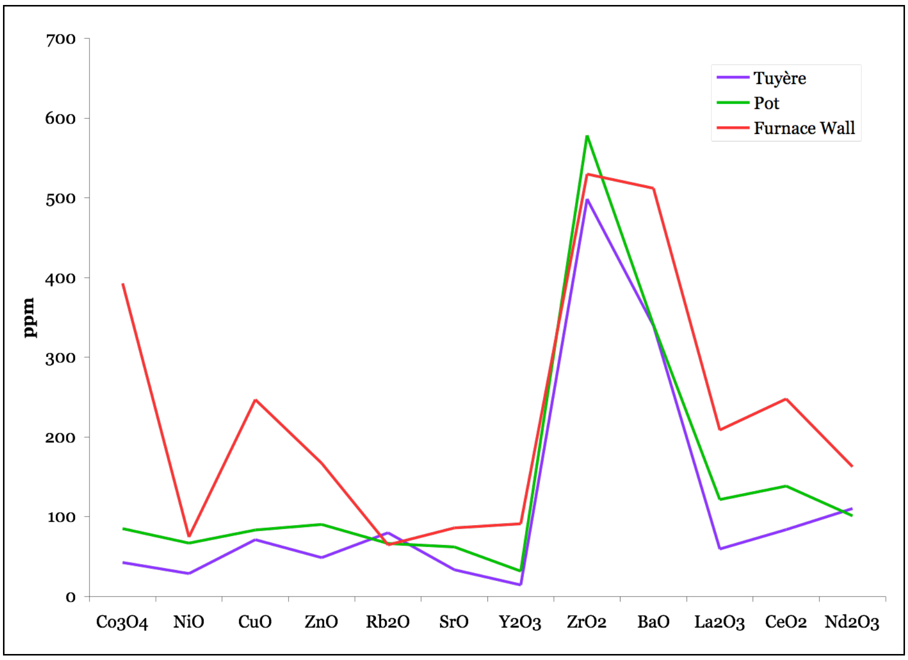


Figure 6.52 Line plot showing trace compounds (less Al_2O_3, SiO_2, FeO) of all analysed ceramics from Kisamura, calculated from PED-XRF data normalised to 100%

Significant variation is clearly apparent in the chemical signatures of all of these samples, although the domestic pottery sample and the tuyère sample share more similarities with each other than with the sample of furnace wall. This is also borne out when the major components of silica, alumina and iron oxide are taken into consideration, as illustrated in the ternary diagram below (Figure 6.53).

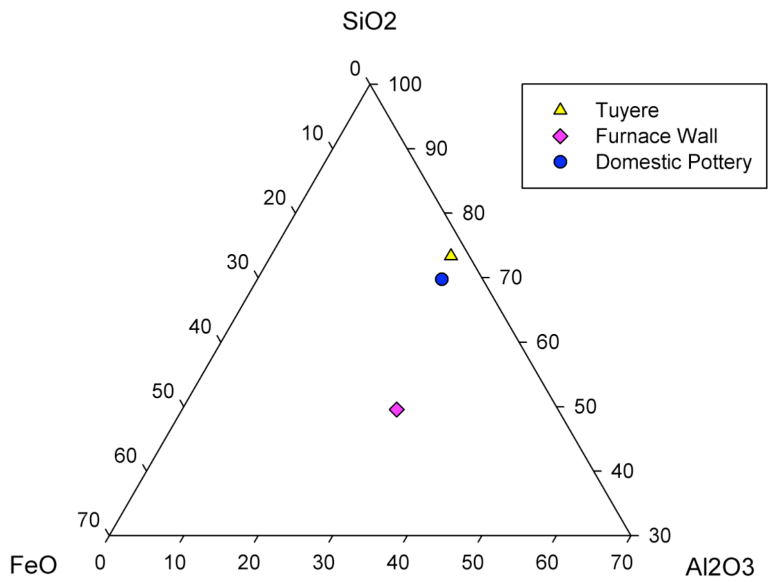


Figure 6.53 Truncated ternary diagram showing the chemical composition of tuyère, furnace wall and domestic pottery samples from Kisamura. Calculated from PED-XRF data, normalised to 100%

Further to this, the SEM-EDS data corroborates the earlier suggestion that the tuyère clay has a proportionally higher alumina content than the domestic pottery sample (Table 6.9). Area analyses of the two matrices free from inclusions give an average alumina to silica ratio of approximately 1:1.4 for the tuyère sample and 1:2.0 for the domestic pottery sample. The alumina content of the ceramic matrix of the tuyère sample is now revealed as being particularly high, at 38wt%. This indicates that it is likely to be made of a kaolinitic clay (*i.e.* one dominated by kaolinite $Al_2Si_2O_5(OH)_4$) – a highly refractory clay that is likely to withstand temperatures of over 1200˚C (*cf.* Freestone and Tite 1986, specifically the refiring experiments on similar crucibles 25843 and 25981). As such, it is unlikely that these ceramics would have made a significant chemical contribution to the smelt (*cf.* also Kirongo discussion).

Other mineral inclusions, aside from quartz, that were identified by SEM-EDS spot analyses of the ceramic material included potassium feldspars and bright (in BSE) iron oxide minerals in the sample of domestic pottery, and ilmenite ($FeTiO_3$) in the tuyère sample. Many of the unanalysed bright white inclusions in the backscattered electron imaging of the domestic pottery sample may also have been ilmenite, which would explain the relatively high bulk titania in both samples.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	FeO	(wt%)
Tuyère	0.1	0.3	38.0	55.1	0.1	2.0	0.4	1.1	3.2	
Pot	0.2	0.5	30.4	59.2	0.3	1.2	0.7	1.5	6.0	

Table 6.9 Averaged SEM-EDS area analyses of the matrix of the tuyère and domestic pottery samples from Kisamura

The higher lime and iron oxide contents would also have meant a relatively lower refractory capacity of the domestic pottery clay as compared to the tuyère clay. It seems, therefore, that more refractory clays were being specially sourced for the manufacture of tuyères at Kisamura.

To summarise, the above results suggest that different clays were being sourced (and used in addition to different tempering choices) to meet the requirements faced by the different ceramic types being used at Kisamura. This would have resulted in mechanical properties that suited their purpose; a technological decision made by their manufacturers most likely in response to the different environments that these ceramics were to be used within, and the different requirements of temperature and atmosphere that they had to withstand, whilst seemingly in keeping with a coherent grog-temper cultural tradition (to be discussed further in Chapter 7).

METALLURGICAL ANALYSES

MACRO-DESCRIPTIONS

The slag that was sampled from Kisamura derived primarily from three clusters of slag blocks in the vicinity of the furnace, as well as from the furnace base itself. In total sixteen blocks were recorded in detail (Table 6.10), most of which were prepared for further analysis. Cluster 1, Slag 6 (C1S6) had multiple samples made from it – from the base, middle and top, as well as from the upper surface (which showed a typical textured ring of slag or 'crown', *cf.* Figure 6.56). These samples were taken in order to investigate the variation that occurred within the single smelt that produced it.

Cluster	Slag #	Complete block?	Width a cms	Width b cms	Depth cms	Weight kg	Samples Top	Middle	Bottom	ED-XRF	OM/SEM-EDS
1	1	Y	40	39	25	35	✔	✔	✔	✔	✔
	2	Y	42	29	27	36	✔	✔	✔	✔	
	3	Y	36	33	28	34		✔		✔	
	4	Y	36	32	30	40	✔	✔	✔	✔	✔
	5	Y	34	29	24	17		✔		✔	
	6	Y	26	30	36	34	✔	✔	✔	✔	✔
	7	Y	31	28	34	35		✔			
2	1	Y	40	35	29	38	✔	✔	✔	✔	
	2	N	39	29	24	34		✔	✔	✔	✔
	3	Y	42	36	30	63	✔	✔	✔	✔	
3	1	N	37	32	25	24		✔		✔	
	2	Y	30	28	26	35	✔	✔	✔	✔	✔
Furnace	1	Y	34	24	20	25		✔		✔	✔
	2	N	26	26	34	28		✔			
	3	N	35	25	14	15		✔			
	4	N	23	20	15	9	✔	✔	✔		

Table 6.10 Summary of macroscopic information recorded for the slag blocks from Kisamura

Further to the slag samples, three fragments of what initially appeared to be possible examples of ore were recovered from Testpit B, from a depth of approximately 20cm beneath the surface (Figure 6.54). These three samples were prepared for PED-XRF and optical microscopy.

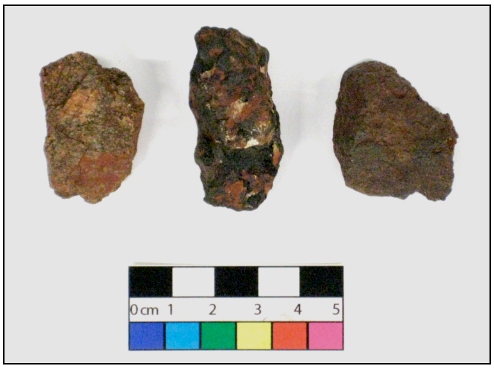


Figure 6.54 Samples of possible ore collected for analysis from Testpit B, Kisamura. Ore C is to the far left, Ore B is in the middle, Ore A is on the far right

All of the slag blocks sampled from this site appeared to be the result of iron smelting within a pit furnace. None showed morphological evidence of tapping. Many of the slag blocks were complete – a much higher proportion than had been seen at other sites. Further to this, many of the slag blocks were remarkably similar in dimension, shape and weight, particularly those from Cluster 1. All the slag blocks in this cluster tended to have a raised, circular rim on their upper surfaces (*cf.* Figures 6.55 and 6.56), and tapered down with a diagonal slope to one side, before ending in a base that appeared to have formed upon an irregular surface rather than a solid furnace bottom.

Figure 6.55 Cluster 1 Slag 2, Kisamura. Scale bar is 30cm

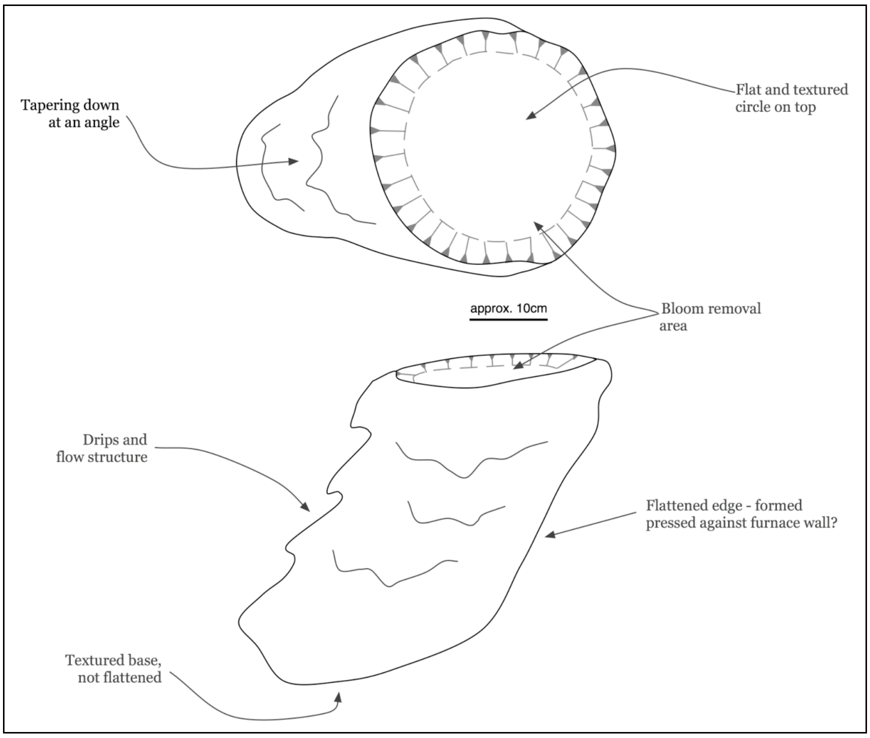


Figure 6.56 Sketch diagram of Cluster 1 Slag 6 in plan (above) and in profile (below)

In colour, the slag blocks from Cluster 1 were bluish to dark grey, appearing bright bluish grey once broken open, and they were dense and difficult to break. Very small grass impressions were present in limited frequency on these blocks. The slag blocks from Clusters 2 and 3 tended to be more fragmented, but those from Cluster 2 especially still bore signs that suggested that originally they were similar in size and shape to those from Cluster 1. Again, these slag blocks were dense and dark bluish-grey and had a limited extent of small grass impressions. On a number of blocks however, were the occasional impressions of triangular-profiled sedges, and even more rarely, what looked like the impressions of *Musa* species and possible dicotyledonous woody plants (Figure 6.57).

The slag samples from the furnace were much smaller, broken slag fragments than the slag blocks from the clusters. Very few morphological features were therefore available to link them to the slag from the clusters, although they were once again dark bluish grey, and bore impressions of small grasses and the occasional sedge.

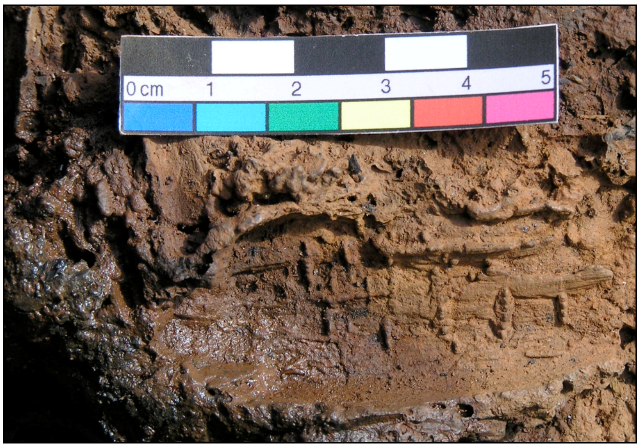


Figure 6.57 Impression of possible dicotyledonous woody plant, Cluster 2 Slag 3 Kisamura

The density, low macro-porosity and the crystalline nature of all of the slag samples from this site – observations repeatedly noted during sample preparation – coupled with the repeated, well defined macro-morphology of the complete slag blocks, suggests that the molten slag from which these blocks formed had a relatively high fluidity.

Analysis

The PED-XRF results, presented in Table 6.8 and reported in full in Appendix Q, show that the compositions of all the slag samples were typical of bloomery slag. The slag samples comprised, on average, approximately 7wt% alumina, 22wt% silica and 53wt% iron oxide – a relatively low iron oxide content. The variation within these major components was also very low, with these compounds having CVs of 15%, 12% and 7% respectively. The alumina to silica ratio of all the samples ranged between 1:2 and 1:4, but averaged solidly at 1:3.

Figure 6.58 shows how little compositional variation there was across the sample set. Significant variation occurs only in titania, vanadium oxide and barium oxide. For both titania and vanadium oxide, this is due to their absence from several samples (i.e. that they register below the detection limits of the PED-XRF). Vanadium oxide is absent in all samples from Cluster 2, from one sample from Cluster 3, and from the furnace slag. Titania is also below detection limits from these same samples, but interestingly, is also absent from two of the four samples (the middle and the top sample) from Cluster 1 Slag 6 (*cf.* Table 6.8). The high CV with regards to barium oxide is explained by the particularly high levels of it in the samples FS1M (1.4wt%), C2S1M (1.7wt%) and C2S2M (2.4wt%), and to a lesser extent in C3S1M (0.9wt%). In other samples, barium oxide averaged at approximately 0.5wt%. Levels this high are not unusual for this region (*cf.* this and previous chapter).

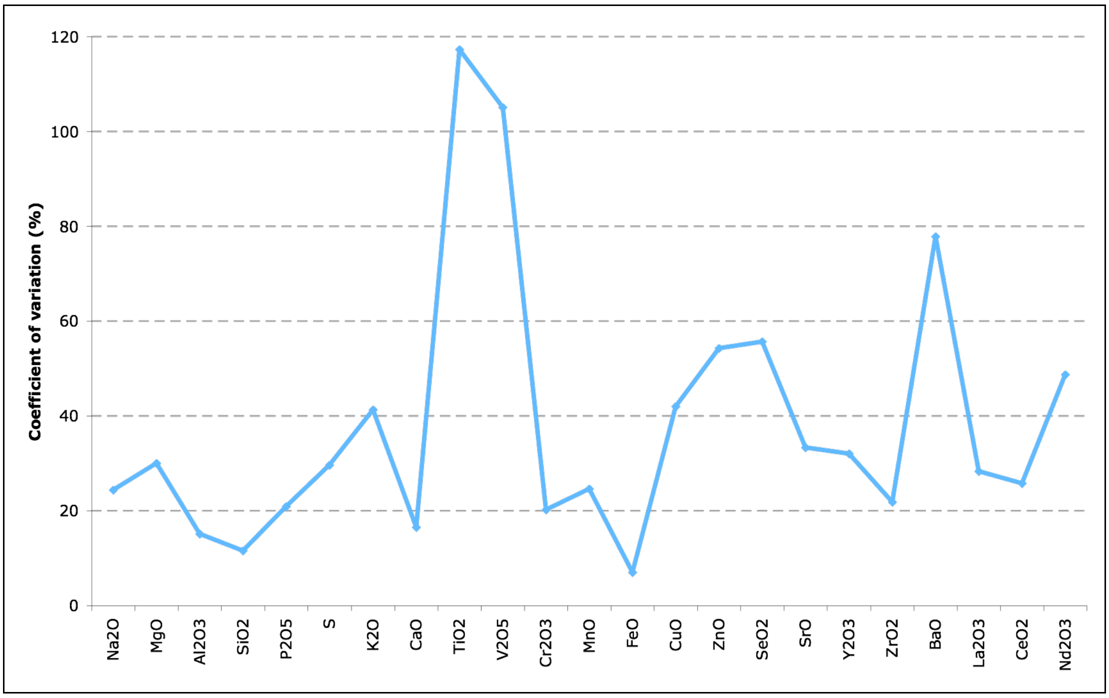


Figure 6.58 Coefficients of variation for all compounds in the sampled slag blocks from Kisamura, calculated from PED-XRF data normalised to 100%

Phosphate was moderately high, ranging between 1 and 2wt%, as was potash, which averaged at 2wt%. Potentially, this may have affected the melting point of the slag (Pleiner 2000: 252). Conversely, lime was relatively low, ranging between 1 and 2wt% with an average of 1.6wt%. Once again, manganese oxide was elevated, with a relatively wide range – between 5 and 12wt% (with a CV of 25%) – and an average of 8wt%, values that are likely to be underestimated by varying degrees (*cf.* Chapter 4). Traces of zinc oxide were also present in all of the slag samples, despite zinc metal's volatility at high temperatures (*cf.* Chapter 6, Part One).

The level of internal heterogeneity present within the single smelt that culminated in slag C1S6 was higher overall than that seen in single slag blocks from other sites (Figure 6.59).

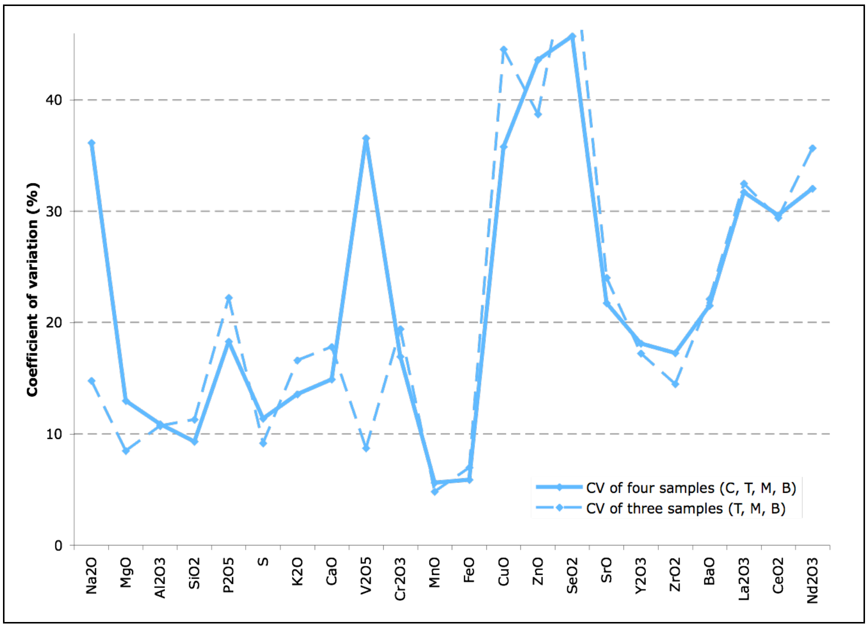


Figure 6.59 Coefficient of variation for all compounds through start-middle-end of a single smelt calculated from three (dashed line) and four (solid line) samples from C1S6

However, initial thoughts that this was due to the inclusion of four rather than three samples (including the upper 'bloom' (crown) sample in addition to the top, middle and bottom samples) were negated once this additional sample was removed from the calculations (demonstrated by the dotted blue line in Figure 6.59). Not only did the removal of this sample make only a very limited reduction in CV for most of the compounds, in some cases (especially phosphate, potash, lime, copper and selenium oxides) it increased the CV. Nevertheless, the major components – silica, iron oxide, alumina, and in these slags, also manganese oxide – had a very low CV (9%, 6%, 11% and 6% respectively). Those compounds with a high level of variation were soda (a light and known variable compound owing to the poor accuracy of the PED-XRF regarding this compound, *cf.* Chapter 4), vanadium oxide (for which much variation was removed once the crown sample was factored out), zinc and selenium oxides (highly volatile), and copper oxide.

When patterns in this variation through the course of the smelt were examined in more detail, a different pattern emerged than that seen at Kyakaturi and Mirongo. Instead of the ore-related oxides rising in the middle of the smelt (*cf.* Table 5.4 and Figure 5.56), and the fuel ash compounds and silica falling, the opposite scenario presents itself here (Table 6.11).

C1S6	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	V_2O_5	Cr_2O_3	MnO	FeO	CuO	ZnO	SeO_2	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3
Beginning	0.23	0.37	6.31	17.55	1.43	0.12	1.99	1.18	0.02	0.08	8.71	57.69	357	8	15	273	82	499	3234	411	686	315
Middle	0.30	0.42	7.82	21.65	2.21	0.13	2.78	1.67	0.02	0.09	8.63	50.44	156	17	56	436	112	639	4897	749	1058	650
Close to end	0.31	0.36	7.01	21.33	2.10	0.14	2.56	1.60	0.02	0.12	7.97	52.53	200	11	50	425	113	658	4895	805	1269	642
Very end	0.12	0.31	8.05	20.92	2.09	0.16	2.54	1.62	0.01	0.09	7.78	52.07	266	22	62	470	129	769	5590	963	1459	747

Table 6.11 PED-XRF data for Cluster 1 Slag 6, Kisamura, showing chemical composition for the beginning (bottom sample), middle (middle sample), and end (top and 'bloom' samples). Those compounds that show a dip in the middle of the smelt are highlighted in pale yellow; those that fall throughout the smelt are highlighted in bright yellow. Those compounds that rise in the middle of the smelt are highlighted in pale pink; those that rise throughout the smelt are highlighted in bright pink

Iron and copper oxides dip in the middle of the smelt; manganese oxide reduces slightly throughout the smelt. Almost every other major and minor compound shows an increase in the middle of the smelt, alumina and all the trace compounds bar copper oxide rise overall through the course of the smelt (Figure 6.60). We can infer from this that the furnace operation is seemingly at its least efficient at the beginning of the smelt, and improves as the smelt progresses and reducing conditions develop, indicated by the drop in ore oxides remaining in the slag towards the end of the smelt. However, although these trends are worthy to note, they are not indicative of any major intra-smelt changes as coefficients of variation remained very low overall.

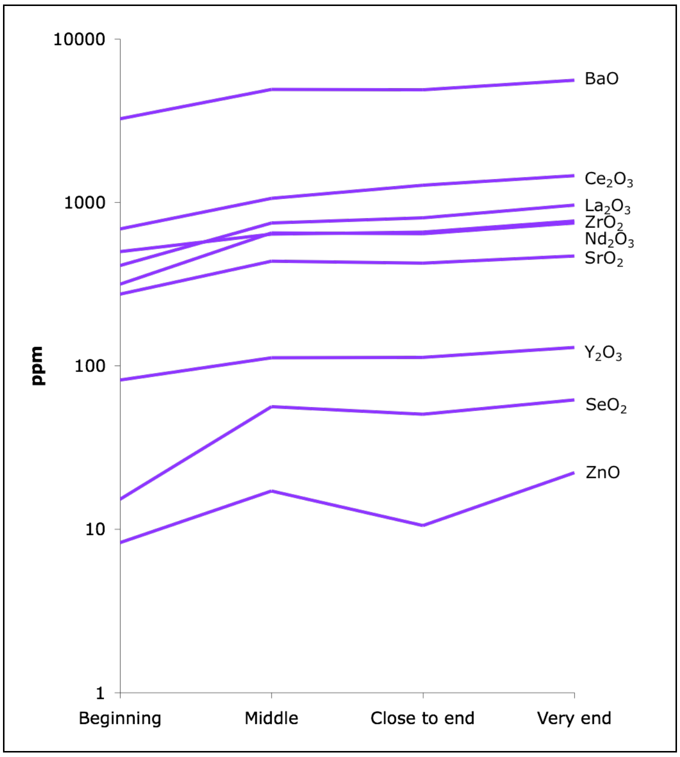


Figure 6.60 Logarithmic line plot showing all trace compounds (except copper) rising in value through the course of the smelt relating to Cluster 1 Slag 6, Kisamura

Microscopically, all the samples (from all clusters, and including the furnace slag) were also very similar; all were relatively homogenous and all had some extent of porosity, mainly round gas bubbles (Figure 6.61). All contained on average 65area% olivines (between 55 and 75area%), blocky in nature, and between 10 and 25area% wüstite, often dendritic (Figure 6.62). The blocky and developed structure of the olivine phases indicates that none of the slag blocks cooled quickly, and the fact that it was also present in this form in the bottom sample from Cluster 1, Slag 6, suggests that even the earliest slag to form per smelt did not solidify within a cool environment. The largest variable was in the amount of matrix in the samples, which ranged from approximately 2area% in the sample from the furnace slag to 30area% in C3S2M (which correspondingly had a low proportion of wüstite).

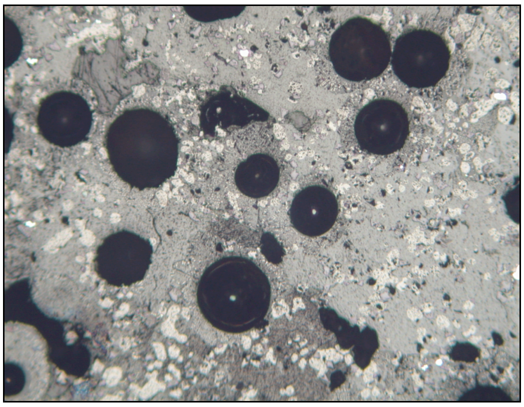


Figure 6.61 Photomicrograph of sample C1S4M, Kisamura, showing round porosity. Image width ≈ 2mm; PPL

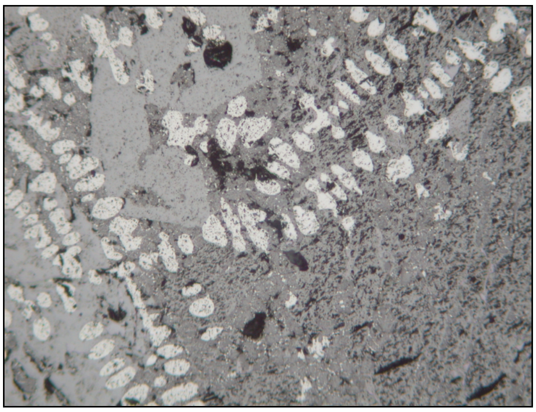


Figure 6.62 Photomicrograph of sample C1S1M, Kisamura, showing dendritic wüstite (light grey), hercynite spinels (mid grey) and knebelite (dark grey). Image width ≈ 1mm; PPL

SEM-EDS analysis revealed that the olivine phases across all samples comprised knebelite, which contained substantial substitution of manganese for iron (on average almost 20wt%, but ranging between 12 and 34wt%). This would have meant that a higher proportion of iron oxides would have remained free to reduce to iron metal, theoretically enabling the removal of more iron from an ore than if the manganese was not present in the system, depending of course upon the other parameters of the smelt.

All SEM-EDS spot analyses of the glassy matrix indicated a composition approaching that of leucite ($K_2O•Al_2O_3•4SiO_2$), with minimal contributions from other compounds. Often, eutectic wüstite was present exsolving from the glassy matrix (see Figure 6.62), and in many samples – most significantly in samples C2S2M and C1S1B – the wüstite had reduced to iron metal, resulting in extensive iron foils or pseudomorphs of the wüstite dendrites from which they derived (Figure 6.63). The presence of these iron foils even within the bottom sample from Cluster 1 Slag 6 is unusual, and might indicate a particularly reducing atmosphere, or an interruption in slag formation that allowed the wüstite in the previous slag accumulation to reduce to iron metal (*cf.* also Chapter 5, Part Two). Schmidt (1997: 119-124) noted similar features in Haya slag, which he interpreted to be the result of localised pockets of reducing conditions created by the charred grass filling the furnace slag pit, which encouraged further iron reduction. Alternatively, the slag may have been exposed to reducing furnace gases after dropping into the slag pit, enabling the top layer of the slag to reduce to metallic iron before the next slag layer dripped on top of it (*cf.* Iles and Martinón-Torres 2009). Importantly, in these slag blocks, this phenomenon does not seem to indicate a highly viscous slag that would not separate from the bloom, but instead a continuation of metal reduction after the slag had dropped into the slag pit. The wüstite and metallic iron phases that were analysed contained a variety of other metallic components, including manganese, titania, alumina, zirconia and copper.

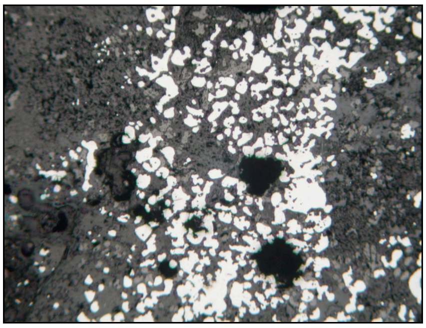


Figure 6.63 Photomicrograph of sample C2S2M, Kisamura, showing foils of iron (white). Image width ≈ 2mm; PPL

The least frequent phases in all samples were small angular crystals often appearing ‘within’ the knebelite phases. With the optical microscope these were often difficult to spot, being only a marginally different colour from the knebelite. However, with the backscatter imaging on the scanning electron microscope they appeared much darker and clearer (Figure 6.64). As in the slag remains from other sites, SEM-EDS analysis showed these phases to be hercynite, with some substitution of manganese and other elements for aluminium. Due to the higher melting point of these hercynitic phases, they would have crystallised before the knebelite, leaving the knebelite to accommodate them within it. The average compositions of all of these phases are presented below in Table 6.12.

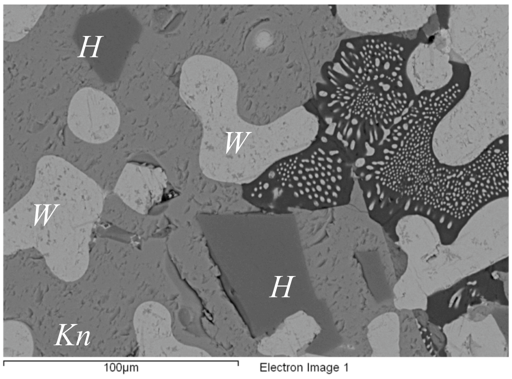


Figure 6.64 BSE image of C1S6M, Kisamura, showing hercynite (H), wüstite (W), and knebelite (Kn), plus eutectic wüstite in a leucitic matrix (dark grey)

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	CuO	ZrO_2	BaO	(wt%)
Hercynite	0.1	0.8	48.6	0.3	0.1				1.0	1.0	2.8	7.5	40.2				
Knebelite		0.9	0.2	30.8	0.5			1.3	0.3			19.3	47.3				
Leucite	0.3		23.4	50.9	0.3	0.5	21.0		0.4			0.5	3.0			1.4	
Wüstite			0.7	0.6	0.3	1.4		0.2	1.2			8.5	88.7		0.8		
Iron													99.6 (Fe)	0.4 (Cu)			

Table 6.12 Averaged SEM-EDS spot analyses for the different phases occurring within slag samples from Kisamura

Several of the slag samples had more unusual minerals and phases within them. Figures 6.65 and 6.66 show some platy crystals that were apparent in the sample from Cluster 1 Slag 4. SEM-EDS spot analyses showed that these were a combination of fayalite and apatite: the lighter, inner areas were fayalitic (although with significant substitutions of alumina, lime, manganese and barium oxides for iron), whereas the darker, outer parts had compositions approaching apatite – $Ca_5(PO_4)_3(OH)$ – with additional manganese and iron oxides as well as the oxides of barium, strontium, lanthanum, cerium and neodymium.

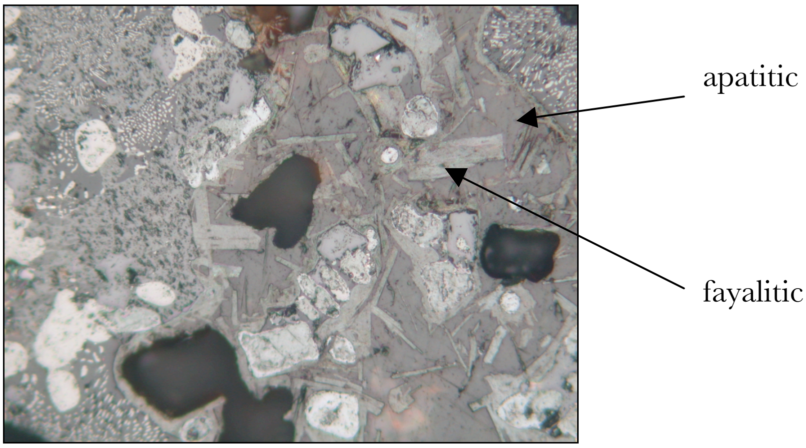


Figure 6.65 Photomicrograph of sample C1S4M, Kisamura. Image width ≈ 0.5mm; PPL

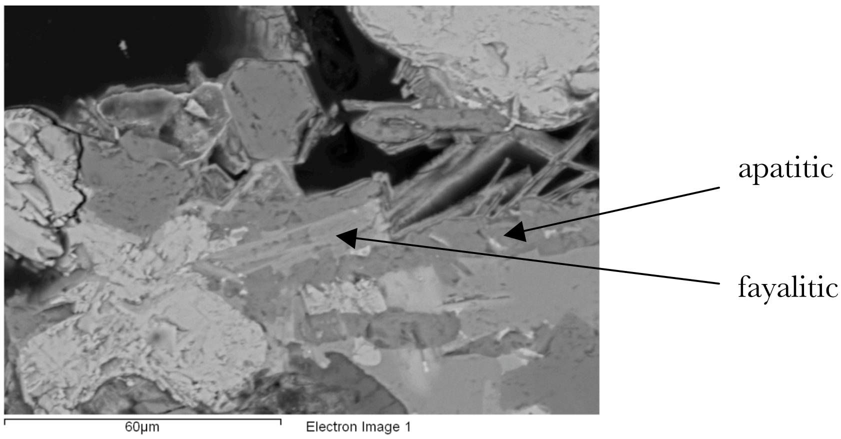


Figure 6.66 BSE image of sample C1S4M, Kisamura

Unusual platy structures in the sample from Cluster 2 Slag 2 (Figure 6.67) turned out to be phases of celsian (barium feldspar, $BaAl_2Si_2O_8$) upon SEM-EDS analysis – reflecting the particularly high barium oxide level noted in the bulk analysis of this sample – with some contributions of phosphate, potash, iron oxide, lime and manganese oxide.

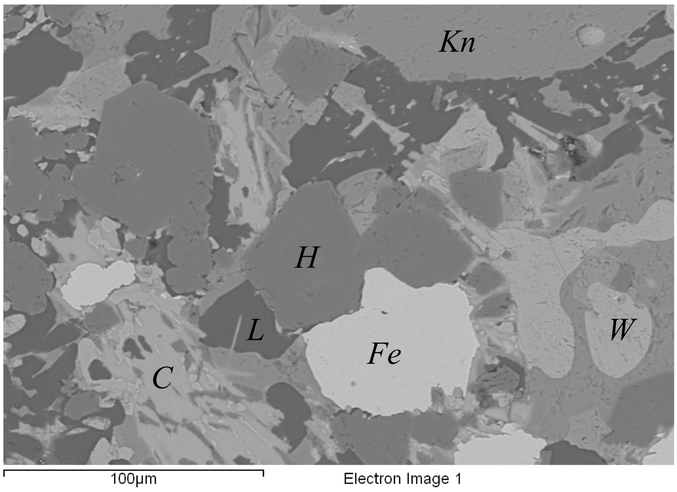


Figure 6.67 BSE image of C2S2M, Kisamura, showing celsian (C), leucite (L), hercynite (H), wüstite (W), knebelite (Kn) and iron (Fe)

The three possible ore samples were also examined microscopically (Figures 6.68, 6.69, 6.70). Samples A and C appeared similar in texture and structure, with quartz prolific across both samples intergrown with iron minerals. Ore B however, appeared very different in structure and texture, corresponding to the significantly different bulk chemical composition of this sample, especially in terms of alumina, lime, manganese oxide and trace compounds. None can be fully representative as their iron oxide levels are too low, yet the potential contributions of each of these possible ore samples will be discussed in the following discussion and summary.

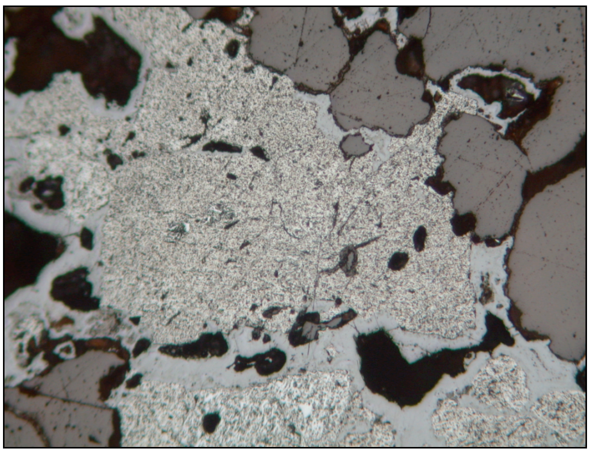


Figure 6.68 Ore A, Kisamura. Image width ≈ 1mm; PPL

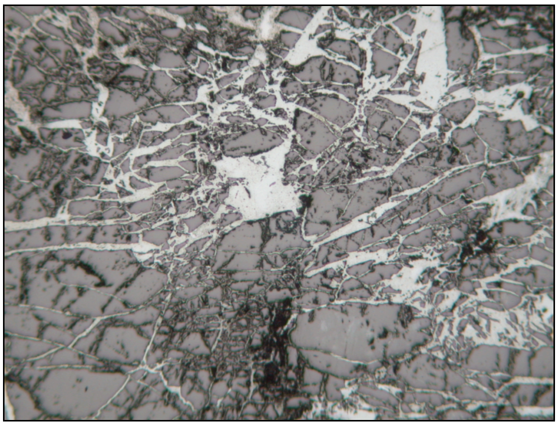


Figure 6.69 Ore B, Kisamura. Image width ≈ 1mm; PPL

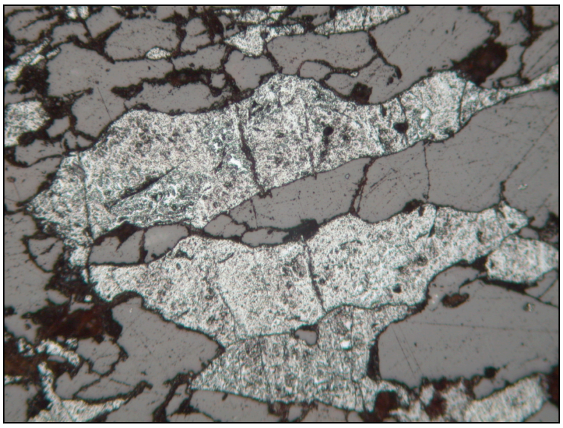


Figure 6.70 Ore C, Kisamura. Image width ≈ 1mm; PPL

DISCUSSION AND SUMMARY

A ternary phase diagram offered further insights into the operation of these smelting systems (Figure 6.71). When plotted, the samples clustered around the trough between the fayalite and hercynite regions, with none falling much above the 1200˚C lines. The high manganese oxide content of the samples, added to the iron oxide axis, pulled the slag samples towards Optimum 2 (*cf.* Rehren *et al.* 2007). The additional manganese in the system, which significantly affects the operation of the smelt profile, would have replaced iron oxide as a fluxing agent for the more refractory alumina and silica in the gangue, as well as combining to knebelite instead of the more iron-rich fayalite (as seen in the SEM-EDS analysis) and allowing more iron oxide to reduce to iron metal. The contribution of alumina and silica seems relatively low, suggesting a limited contribution from the technical ceramics. This ties in with the identification of the highly refractory clays earlier in the chapter, which are likely to have been able to withstand temperatures of well over 1200°C.

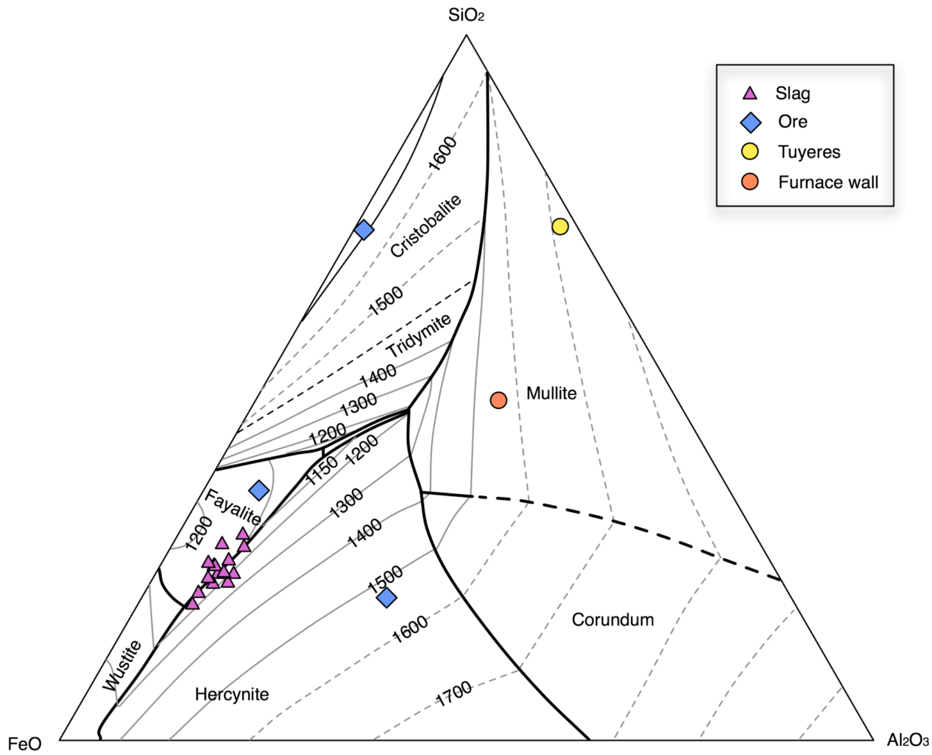


Figure 6.71 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO, with plots for all Kisamura samples (phase diagram adapted from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%; slag samples are plotted in terms of Al_2O_3+TiO_2 – SiO_2 – FeO+MnO+CaO

By moving on to the possible ore samples that were excavated from testpit B, it is possible to postulate further as to the ingredients of the smelts. Even if these fragments were never intended to be used in the smelt, they can give an interesting and relevant indication as to what the local geology may have been able to offer the smelters working at Kisamura.

One, Ore C would – at least in its analysed state, dominated by silica and with an iron oxide content of less than 30wt% – have been too low grade to have been viable as an iron ore in its own right, and as such will not be further discussed. Ores A and B however were more intriguing. Starting with Ore B, this also had a very low iron oxide content – even lower than that of Ore C – at just under 20wt%. What was noteworthy however, was the elevated manganese oxide content of 23wt%. Perhaps this, or a similar mineral, was the source of the manganese oxide in the slag samples from this site? Several other compounds present in the slag would also be explained by the use of this type of ore. With a zinc oxide content approaching 0.1wt%, the use of this rock would explain the presence of zinc oxide traces in the slag, despite the volatility of this metal; lime, and barium and neodymium oxides in the slag would also be accounted for in this way as they too registered significant amounts in the bulk chemical analysis of this material. Alumina was also relatively high in this mineral, and if the technical ceramics were not making a significant contribution to the slag melt, this may have been a further source of alumina in the smelt. The high nickel oxide content (c. 0.1wt%) apparent in this sample is not incongruous with its absence from the slag samples; nickel, like cobalt, is likely to partition completely into the forming iron bloom (Desaulty *et al.* 2009).

Nevertheless, the low iron oxide content of this sample would not have been sufficient to produce iron metal. It is possible therefore that this is a further example of a manganese-rich material used in conjunction with an iron-rich ore, as suggested previously by the results from Mirongo Group 2 (Chapter 6 Part 2). The final possible ore material analysed from Kisamura (Ore A) did have a higher iron oxide content of just below 60wt%, with a silica content of nearly 35wt%; this may represent a possible complementary ore to the manganese material. In fact, the slag from Group 2 of Mirongo was relatively similar in most compounds to these slag remains from Kisamura (Table 6.13). Further parallels between these sites, including the presence of banana impressions in the slag, will be discussed in Chapter 7.

	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	CuO ppm	NiO ppm	ZnO ppm	SeO_2 ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm
Kisamura	0.25	0.32	7.07	21.93	1.68	0.14	1.82	1.65	0.06	0.02	0.10	8.19	52.75	281	/	23	47	419	104	770	7677	850	1060	807
Mirongo Group 2	0.19	0.87	8.30	30.41	1.27	0.13	1.60	2.83	/	0.03	0.10	10.91	40.41	228	17	/	/	558	80	410	17921	1199	961	1803

Table 6.13 Comparison of averaged PED-XRF data for Kisamura slag samples and Mirongo Group 2 slag samples

The hypothetical use of two ores is borne out by the factor analysis that was applied to the slag samples from this site (Table 6.14, and Appendix R). Here, the major components associated with the manganese material's bulk chemical profile (Ore B) – alumina, and manganese, zinc, barium and neodymium oxides – show a positive correlation together, as well as a negative correlation with iron oxide. This negative correlation suggests that the more manganese oxide present, the more efficient the system is and the less iron remains in the slag. The iron oxide on the other hand, correlates with titania and vanadium oxide, suggesting that these enter the smelt from the same source. Titania and vanadium oxide were indeed present in the bulk analyses of Ore A, and absent from the manganese material Ore B. Cobalt oxide, present in this ore but absent from the slag samples, would not negate this possibility, as cobalt is most likely to partition into the iron metal (Desaulty *et al.* 2009). The cumulative addition of zinc oxide from both of these rocks (Ore A and Ore B) would support the presence of low quantities of it in the slag. These arguments appear to bolster the proposal that at least two 'ore' materials were being used in these smelts, similar to the Mirongo Group 2 scenario, and potentially also to the recent ethnographic work regarding the two ores documented by Buchanan (1974a) and Childs (1998a) (see further discussion in Chapter 7).

	CaO	SrO	Y_2O_3	ZrO_2	La_2O_3	CeO_2	P_2O_5	SiO_2	Cr_2O_3	CuO	SeO_2	MgO	K_2O	FeO	TiO_2	V_2O_5	Al_2O_3	MnO	ZnO	BaO	Nd_2O_3	
CaO		0.6	0.7	0.8	0.6	0.6	0.1	0.3	-0.3	0.2	-0.4	-0.2	-0.5	-0.5	-0.5	-0.6	0.2	0.5	0.5	0.5	0.7	CaO
SrO	0.6		0.8	0.6	0.6	0.7	0.5	-0.1	-0.3	0.6	-0.1	-0.4	-0.3	-0.2	-0.5	-0.5	0.2	0.3	0.4	0.1	0.2	SrO
Y_2O_3	0.7	0.8		0.5	0.3	0.8	0.3	0.1	-0.5	0.4	-0.4	-0.5	-0.5	-0.7	-0.7	-0.7	0.5	0.7	0.6	0.4	0.5	Y_2O_3
ZrO_2	0.8	0.6	0.5		0.7	0.5	0.2	0.3	-0.4	0.3	-0.1	-0.3	-0.4	-0.3	-0.1	-0.2	-0.1	0.2	0.2	0.3	0.5	ZrO_2
La_2O_3	0.6	0.6	0.3	0.7		0.3	0.4	0.2	-0.2	0.2	0.3	0.1	0.0	0.1	0.0	0.1	-0.4	-0.3	-0.1	-0.2	0.0	La_2O_3
CeO_2	0.6	0.7	0.8	0.5	0.3		0.5	-0.1	-0.2	0.4	-0.1	-0.4	-0.2	-0.5	-0.5	-0.6	0.6	0.4	0.4	0.5	0.6	CeO_2
P_2O_5	0.1	0.5	0.3	0.2	0.4	0.5		-0.4	0.0	0.2	0.4	0.2	0.5	0.1	0.0	0.1	0.1	-0.3	-0.3	-0.3	-0.2	P_2O_5
SiO_2	0.3	-0.1	0.1	0.3	0.2	-0.1	-0.4		-0.3	-0.5	0.0	-0.1	-0.2	-0.6	-0.2	-0.1	0.0	0.3	0.4	0.1	0.2	SiO_2
Cr_2O_3	-0.3	-0.3	-0.5	-0.4	-0.2	-0.2	0.0	-0.3		-0.1	0.3	0.3	0.3	0.4	0.2	0.4	0.0	-0.5	-0.1	-0.1	-0.1	Cr_2O_3
CuO	0.2	0.6	0.4	0.3	0.2	0.4	0.2	-0.5	-0.1		-0.1	-0.4	-0.3	0.2	-0.2	-0.3	0.1	0.1	0.3	0.2	0.2	CuO
SeO_2	-0.4	-0.1	-0.4	-0.1	0.3	-0.1	0.4	0.0	0.3	-0.1		0.2	0.6	0.4	0.5	0.7	-0.2	-0.8	-0.4	-0.5	-0.5	SeO_2
MgO	-0.2	-0.4	-0.5	-0.3	0.1	-0.4	0.2	-0.1	0.3	-0.4	0.2		0.6	0.4	0.5	0.5	-0.5	-0.6	-0.6	-0.5	-0.5	MgO
K_2O	-0.5	-0.3	-0.5	-0.4	0.0	-0.2	0.5	-0.2	0.3	-0.3	0.6	0.6		0.4	0.4	0.6	-0.3	-0.7	-0.8	-0.6	-0.6	K_2O
FeO	-0.5	-0.2	-0.7	-0.3	0.1	-0.5	0.1	-0.6	0.4	0.2	0.4	0.4	0.4		0.7	0.7	-0.7	-0.8	-0.7	-0.6	-0.7	FeO
TiO_2	-0.5	-0.5	-0.7	-0.1	0.0	-0.5	0.0	-0.2	0.2	-0.2	0.5	0.5	0.4	0.7		0.9	-0.6	-0.8	-0.6	-0.5	-0.6	TiO_2
V_2O_5	-0.6	-0.5	-0.7	-0.2	0.1	-0.6	0.1	-0.1	0.4	-0.3	0.7	0.5	0.6	0.7	0.9		-0.6	-0.9	-0.6	-0.5	-0.6	V_2O_5
Al_2O_3	0.2	0.2	0.5	-0.1	-0.4	0.6	0.1	0.0	0.0	0.1	-0.2	-0.5	-0.3	-0.7	-0.6	-0.6		0.6	0.7	0.6	0.6	Al_2O_3
MnO	0.5	0.3	0.7	0.2	-0.3	0.4	-0.3	0.3	-0.5	0.1	-0.8	-0.6	-0.7	-0.8	-0.8	-0.9	0.6		0.6	0.6	0.6	MnO
ZnO	0.5	0.4	0.6	0.2	-0.1	0.4	-0.3	0.4	-0.1	0.3	-0.4	-0.6	-0.8	-0.7	-0.6	-0.6	0.7	0.6		0.6	0.6	ZnO
BaO	0.5	0.1	0.4	0.3	-0.2	0.5	-0.3	0.1	-0.1	0.2	-0.5	-0.5	-0.6	-0.6	-0.5	-0.5	0.6	0.6	0.6		1.0	BaO
Nd_2O_3	0.7	0.2	0.5	0.5	0.0	0.6	-0.2	0.2	-0.1	0.2	-0.5	-0.5	-0.6	-0.7	-0.6	-0.6	0.6	0.6	0.6	1.0		Nd_2O_3

Table 6.14 Correlation matrix generated using SPSS v.17.0 software, Kisamura. Shading is as in Table 5.9 (Mirongo)

Alumina shows no correlation with silica, which also backs up the earlier suggestion that alumina is not entering the system from the technical ceramics. Silica does not show significant correlation – positive or negative – with any other compound. This could indicate two alternative situations. Either silica is being added separately as a flux as suggested at Kyakaturi (Chapter 5, Part One), or it is entering the system from a number of sources so that it shows correlations with none. It is worth remembering that silica levels are not particularly high in these slag blocks, so the former suggestion appears less likely. Also, both of the possible ores being discussed – Ore A and Ore B – showed significant levels of silica; it is likely that both of these sources (if indeed used) might have contributed silica into the system.

Once again, to test the feasibility of these scenarios, a crude mass balance was attempted, but with these proportions of silica to iron oxide in the analysed sample it was not possible to make it work. It is important to remember that these suggested ores were not related directly to the furnace, and can really only be taken as an indication of the background geology of the area, and the kinds of materials that these smelters might have utilised in the past. A more detailed discussion of the possible application of manganese rich materials in smelting episodes in western Uganda will be presented in Chapter 7.

The final issue to ascertain was whether the Kisamura slag blocks could have originated from a furnace similar to the archaeological furnace remains presented earlier in this chapter. Unlike the slag blocks at, for example, Kyakaturi, where the slag almost filled the furnace base and reflected clearly the shape of the furnace bottom (*cf.* Figure 5.16), the slag blocks at Kisamura appeared to have petered out rather than solidifying against the solid base of a furnace. Not unusual in itself, this did mean that the nature of the furnace morphology had to be inferred through other means, and the excavated furnace remains at Kisamura had appeared atypical.

Luckily, a slag block very similar in shape and external morphology to those seen at Kisamura had been excavated, in-situ, from the furnace at Kirongo (Figure 6.72, and *cf.* Figures 6.6 and 6.8). Because of the striking morphological similarities, this presented an ideal opportunity to try and reconstruct the furnaces that may have formed the slag blocks at Kisamura. Although the Kirongo slag shared a similar morphology to those at Kisamura – a flat, circular top, off-centre, tapering down on a diagonal slope to an irregular base – it was somewhat smaller than the average (i.e.

complete and unfractured) slag at Kisamura. The diameter of the uppermost circle was approximately 20cm at Kirongo, as compared to almost 35cm at Kisamura; the depth of the Kirongo slag was 22cm, rather than an average of 28cm at Kisamura (which in actual fact ranged up to a maximum depth of 36cm). The furnace base in Kirongo was 50cm in diameter and 30cm deep. This might suggest that the Kisamura slag formed in a furnace with a similar style (and use pattern) to that at Kirongo, albeit, slightly bigger.

Figure 6.72 Furnace slag, Kirongo

However, the excavated furnace remains at Kisamura did not appear to confirm to this style. Instead, it seems to comprise a very shallow furnace 'hollow', of only a maximum of 15cm deep, with furnace walls built up around it. As mentioned, similar furnaces with similarly shallow furnace pits (c. 20cm), have been documented in the wider Great Lakes region confined mainly to southern Rwanda and Burundi (Célis 1987; Craddock *et al.* 2007; Humphris 2010). However, these shallow furnaces don't tend to produce large slag blocks similar in form and size to those seen here. Unfortunately, if it is not possible to attribute these slag blocks to the furnace remains, it is also not possible to attribute the radiocarbon date generated from charcoal from the furnace to the slag blocks.

In summary, the smelting system inferred from the remains at Kisamura bears some striking similarities to that from Mirongo Group 2. Manganese oxide appears to be entering the system separately from the iron ore, which might correlate with ethnographic records of more recent smelting from this local area. It appears that the highly refractory ceramics were unlikely to have made a significant contribution to the melt, with both silica and alumina entering the system from the ore materials. Unfortunately, the nature of the furnace from which these slag blocks derived is unclear, yet the analysis of the remains from this site has raised a number of interesting and valuable lines of inquiry, the implications of which will be addressed in detail in Chapter 7.

PART THREE: RUKOMERO (RKM)

between 17th and 20th centuries (1661-1954 cal. AD)

SITE DESCRIPTION

Rukomero (KYS103) is the final site to be discussed within this section, and the most southwesterly of the Mwenge sites that were excavated as part of this research. Rukomero is situated in a landscape somewhat distinct to that of the other sites of this chapter; it sits to the far west of Mwenge county, close to the border with Kibale county and the Kibale Forest Reserve. To the northwest, before the forest begins, and to the north of the site, extensive tea plantations dominate the landscape; to the south and east, the landscape rises and falls more dramatically than in other regions of Mwenge, and is comparatively difficult to traverse, with larger streams (e.g. Katera) feeding into marshes that cut through steep hillsides. Indeed, this site was not easy to reach, with the final drivable track ending at Lwensenene (see Figure 6.1). Springs to the south and west feed into the major Mpanga river that demarcates the border between Mwenge and Kibale counties.

The local area is rich in historical interest: the remains of Lugard's Fort Lorne (*cf.* Furley 1959) loom over the surrounding landscape, and the fort's accompanying earthworks – now very overgrown – form modern boundaries for the compounds and gardens of many local residents. Evidence for iron production was noticeably much less dense than in other areas of Mwenge that had previously been surveyed during this research, although several archaeometallurgical sites were found in the general area during the survey. A large number of iron ore mining pits (KYS 100) were apparent on a south-facing hillside close to the track between Lwensenene and Rukomero, approximately half a kilometre from the archaeometallurgical site discussed here. Two dense scatters of pottery (and to a lesser extent, slag) were also found (KYS102 and KYS104), with accompanying rich ashy deposits. In order to supplement the archaeological material, KYS102, situated approximately 800m to the east of the archaeometallurgical site (KYS103), was also chosen for excavation. The presence of many different types of decorated pottery at this site raised hopes that some stratified deposits there might contribute to a pottery sequence for the area.

The site of KYS103 was limited to the remains of two furnace bases that were eroding from the ground at the entrance to a compound on the southeasterly edge of the hamlet of Rukomero (Figure 6.73). No large accumulations of slag blocks were apparent, nor did the elderly couple who lived next door have any recollection of smelting activity in the area – an unusual occurrence in itself during survey, as most elderly people we spoke to had some knowledge of either smithing or smelting. It was therefore assumed that this site had the potential to be relatively old, and so excavation was decided upon despite the lack of associated features or slag.

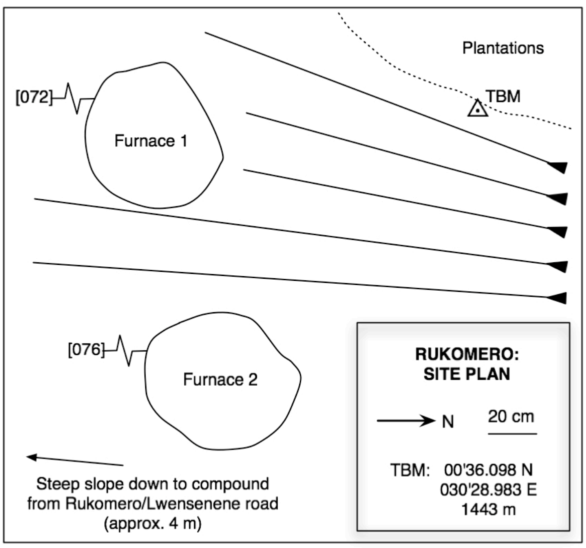


Figure 6.73 Site plan of Rukomero (KYS103)

EXCAVATIONS

The furnace remains were the only features to be excavated at the archaeometallurgical site: exposed areas of the surrounding ground showed no sign of any further archaeological features, and the remaining uncultivated land bore only very thin deposits that would not have harboured stratified deposits. The furnaces themselves were separated by less than a metre and appeared similar in size and shape from the surface (Figure 6.74).

Figure 6.74 Furnace bases at Rukomero indicated by circles of darker soils in red surrounding clays

The similarities continued underground, and excavation revealed them both to consist of furnace pits measuring approximately 70cm in diameter, and up to 60cm deep (Figures 6.75, 6.76 and 6.77). Both contained substantial in-situ slag blocks surrounded by dark, ashy furnace fills very rich in charcoal fragments. The furnace fills in both instances were very loose and pliable, and they contrasted clearly with the distinct cut of the furnace pits into the red natural clay.

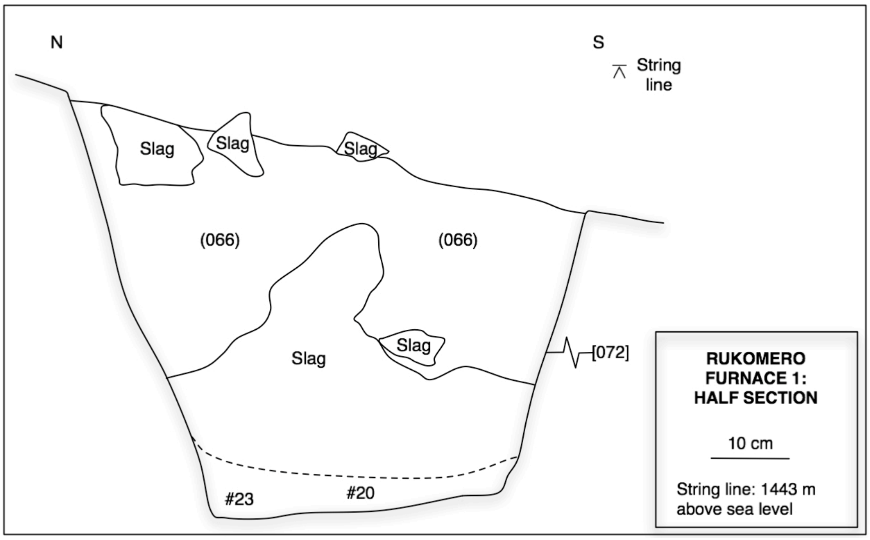


Figure 6.75 Composite profile of Furnace 1, Rukomero

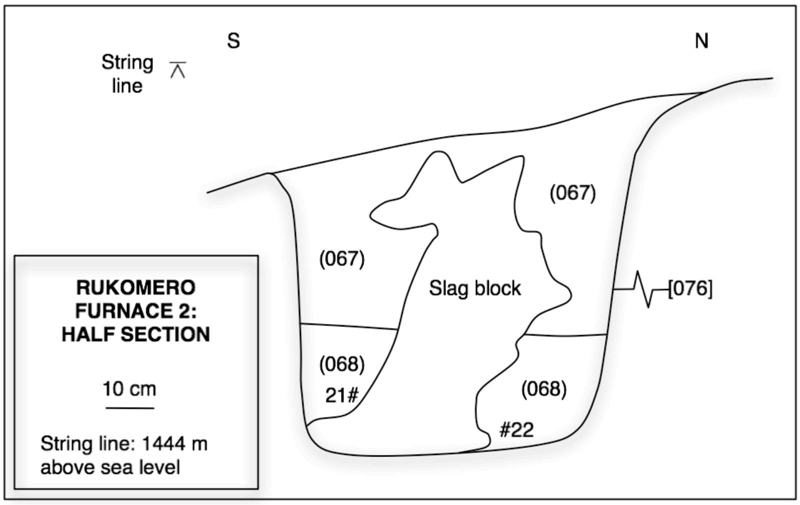


Figure 6.76 Composite profile of Furnace 2, Rukomero

Furnace 1 contained three large pieces of slag that were recorded individually, as well as nearly 10kg of slag fragments, from which a sample was collected. The upper fill of Furnace 2 was similar to the fill of Furnace 1, and again contained three slag blocks that were recorded individually as well as nearly 20kg of small slag fragments (of which a sample was retained). A very small number of undecorated pottery sherds were also present. The lower fill of Furnace 2 was exceptionally charcoal rich, comprising about 10% charred plant material – dominantly large reeds – with no other inclusions or finds. Samples of furnace wall (differentially preserved within the furnaces, *cf.* Figure 6.77) were taken from both furnaces, and the bases of both furnaces were dug through to ensure there were no further remains.

Figure 6.77 Fully excavated furnaces at Rukomero, looking south. Furnace 1 is to the right of the picture, Furnace 2 is to the left

No other slag blocks were found in the vicinity, so the six slag blocks excavated from the furnace were the only slag blocks that were recorded from this site.

Two radiocarbon dates were generated, one from each furnace. Wood charcoal sampled from Furnace 1 (*cf.* Figure 6.75, #20) gave a date of 148 ±25 BP, which calibrates to a date of 1667-1949 with a 95.3% probability (OxCal 4.1; IntCal09; Bronk Ramsey 2009). Carbonised elephant reed gathered from Furnace 2 (*cf.* Figure 6.76, #22) gave a date of 170 ±28 BP, which calibrates to 1661-1954 cal. AD with a probability of 95.4% (OxCal 4.1; IntCal09; Bronk Ramsey 2009; Reimer *et al.* 2009).

Concurrently with the furnace excavation, a second team was excavating a 2m by 3m trench at the pottery-rich compound 800m to the east of the furnaces (KYS102). However, the pottery-rich deposits were found to be very thin (Figure 6.78), and were unable to shed light on a pottery sequence as had been hoped. The pottery finds excavated from this site – which included some dimple-based ware (Figure 6.79) will be published elsewhere, as they have no direct relevance to the archaeometallurgy of the area, as far as it can be inferred.

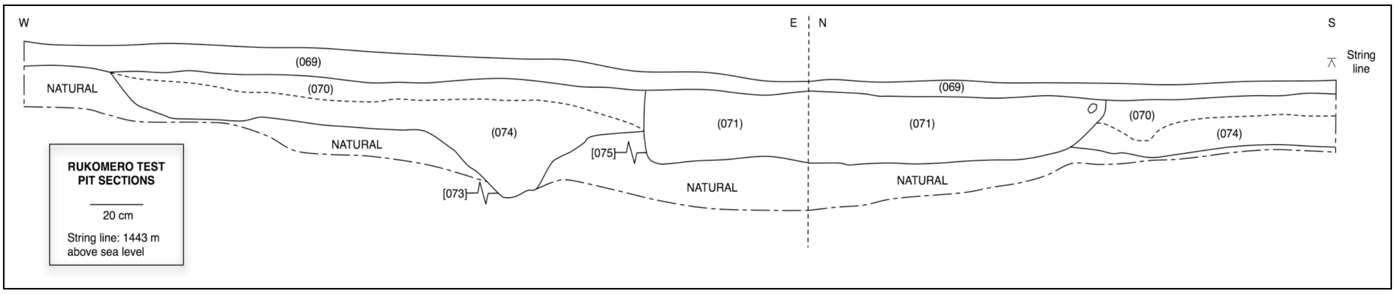


Figure 6.78 Section drawing of Rukomero testpit

Figure 6.79 Sherds from a single dimple based pot excavated from the testpit at Rukomero, context (070), KYS102

Analytical Results and Interpretation

Technical Ceramic Analyses

As at Kirongo, no tuyères were found in the vicinity of the furnaces at Rukomero, nor in the surrounding area. As such the only ceramics available for analysis were samples from both furnace walls (which were analysed by PED-XRF), and a sample of undecorated domestic pottery that was excavated from the upper fill of Furnace 2. This sample was examined using optical microscopy and PED-XRF analysis.

Figure 6.80 Domestic pottery sample excavated from Rukomero Furnace 2 (067)

The pottery sample appeared highly eroded on the surface, suggesting that it had originally been low fired and was susceptible to water damage after deposition. Frequent inclusions were visible macroscopically (*cf.* Figure 6.80), including small quartz fragments and occasional grog. Mica was also visible within the fabric of this sample. Microscopically, these observations were confirmed (Figure 6.81), and the low-fired nature of this ceramic was reinforced by the presence of voids where quartz grains had fallen out during sample preparation (Figure 6.82).

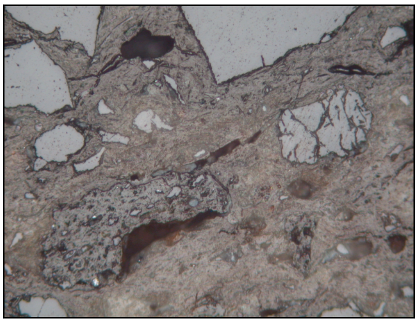


Figure 6.81 Grog and quartz inclusions in domestic pottery, Rukomero. Image width ≈ 1mm; PPL

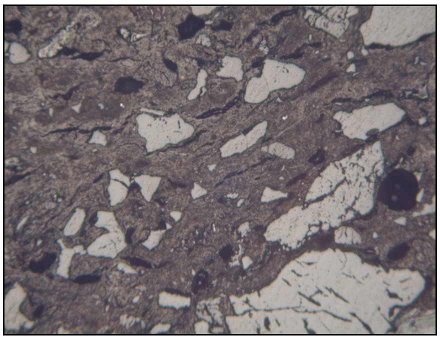


Figure 6.82 Domestic pottery sample, Rukomero, showing quartz inclusions, no vitrification and the presence of round voids (mid-left of image) where inclusions had fallen out during sample preparation. Image width ≈ 2mm; PPL

None of the quartz inclusions within the matrix of the domestic pottery sample were significantly cracked. No SEM-EDS analysis was undertaken on this sample, but the PED-XRF results are presented below in Table 6.15, and reported in full in Appendix S, along with the results of the furnace wall analyses.

	Major and minor compounds													
RUKOMERO (RKM)	Na_2O wt%	MgO wt%	Al_2O_3 wt%	*SiO_2 wt%*	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
				original	adjusted									
Furnace 1 Slag 1 M	0.17	≤0.09	4.34	*27.72*	25.92	0.04	0.09	0.28	0.51	0.18	0.02	0.01	2.56	63.57
Furnace 1 Slag 2 M	0.25	0.13	4.56	*26.91*	24.76	0.05	0.05	0.52	0.90	0.15	≤0.00	0.02	2.98	62.94
Furnace 1 Slag 3 M	0.18	0.13	4.37	*27.75*	25.95	0.07	0.06	0.43	0.80	0.18	0.01	0.02	2.73	62.84
Furnace 2 Slag 1 M	0.19	0.24	5.47	*36.26*	36.26	0.07	0.06	0.92	1.76	0.19	0.01	0.02	3.10	51.50
Furnace 2 Slag 2 T	0.24	0.17	6.33	*35.34*	35.34	≤0.02	0.04	0.61	1.18	0.23	≤0.00	0.02	3.23	52.42
Furnace 2 Slag 3 M	0.29	≤0.10	6.20	*34.89*	34.89	0.04	0.05	0.62	1.02	0.20	0.00	0.02	3.25	53.13
Furnace 1 Ore	≤0.17	≤0.05	3.12	*18.14*	14.60	0.04	0.04	0.05	0.01	0.02	0.01	0.01	0.05	78.27
Furnace 2 Ore	/	≤0.05	1.53	*14.64*	11.27	/	0.02	0.04	0.01	0.01	/	0.02	0.04	83.59
Furnace 1 Furnace Wall	0.24	0.32	26.64	*58.30*	58.30	0.43	0.10	1.53	0.07	1.20	0.03	0.03	0.09	10.74
Furnace 2 Furnace Wall	0.27	0.35	26.42	*58.97*	58.97	0.35	0.08	1.42	0.04	1.15	0.01	0.02	0.14	10.51
Furnace 2 Pot	0.34	0.63	30.25	*61.02*	61.02	0.06	0.08	1.35	0.14	1.38	0.01	0.02	0.04	4.35

	Trace compounds											
RUKOMERO (RKM)	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	Rb_2O ppm	SrO ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Furnace 1 Slag 1 M	463	/	78	/	/	76	97	3556	87	96	206	99.88
Furnace 1 Slag 2 M	320	/	63	/	/	144	80	4347	73	124	292	107.17
Furnace 1 Slag 3 M	383	/	54	/	/	101	85	3361	100	77	≤267	105.55
Furnace 2 Slag 1 M	204	/	16	/	/	164	97	1236	86	263	≤247	110.68
Furnace 2 Slag 2 T	≤228	/	38	/	/	104	134	874	125	263	≤185	108.46
Furnace 2 Slag 3 M	153	/	33	/	/	101	116	1320	143	303	≤76	106.99
Furnace 1 Ore	780	/	/	/	/	/	/	/	178	82	/	105.78
Furnace 2 Ore	776	/	/	/	/	/	/	/	/	≤52	/	105.97
Furnace 1 Furnace Wall	182	46	104	54	111	25	745	547	200	686	174	86.35
Furnace 2 Furnace Wall	203	45	112	61	116	21	679	418	283	528	204	86.56
Furnace 2 Pot	74	37	46	69	72	73	792	973	423	540	348	87.20

Table 6.15 PED-XRF compositional data for all samples from Rukomero, normalised to 100%. All values are the average of the three analyses of each sample reported in Appendix S. 'Analytical total' shows the analytical total prior to normalisation

Silica levels in both of the furnace wall samples measured approximately 58wt% compared to 61wt% in the domestic pottery; alumina measured around 26wt%, as opposed to 30wt% in the pot sample. In the absence of tuyères from this site, it may be particularly pertinent to note that the ratio of alumina to silica in the furnace wall samples is just under 1:2.

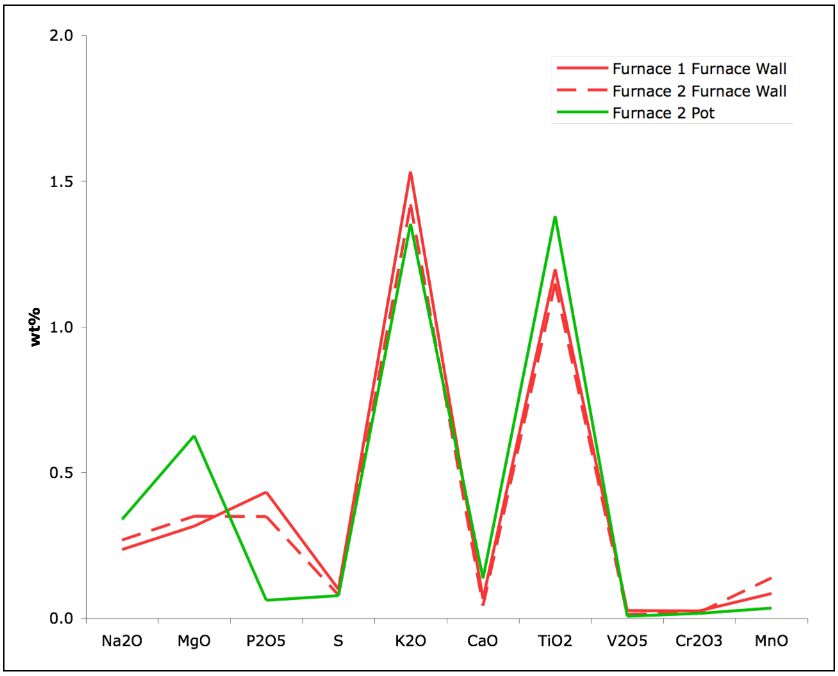


Figure 6.83 Line plot showing major and minor compounds (less Al_2O_3, SiO_2, FeO) of all ceramics from Rukomero, calculated from PED-XRF data normalised to 100%

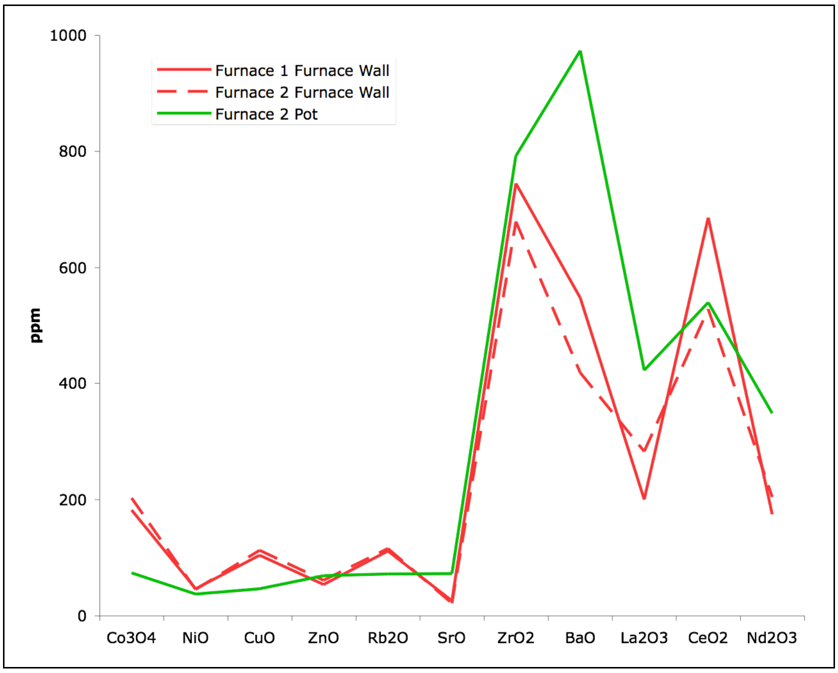


Figure 6.84 Line plot showing trace compounds of all ceramics from Rukomero, calculated from PED-XRF data normalised to 100%

Compositional variation between the two furnace wall samples was minimal, as can be seen from Figures 6.83, 6.84 and 6.85. However, these figures also show that the furnace walls are compositionally distinct from the sample of domestic pottery. The most significant variation (between furnace walls and domestic pottery) occurs in levels of alumina and iron oxide, and the trace compounds. Compared to the very close match for the furnace linings, it appears that a slightly different clay may have been being used to manufacture domestic pottery for use at or around this site.

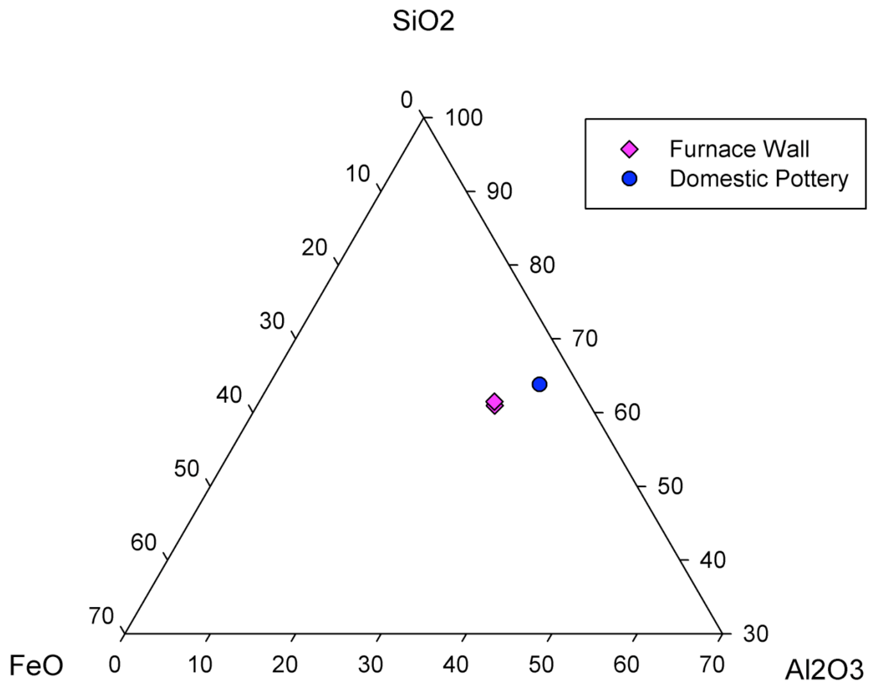


Figure 6.85 Truncated ternary diagram showing the chemical composition of furnace wall and domestic pottery sample from Rukomero. Calculated from PED-XRF data, normalised to 100%

The high alumina content of the furnace walls coupled with the relatively low silica may have meant that the furnace walls would have been relatively refractory. However, this was coupled with a moderately high iron oxide content of approximately 10wt%, which would have lowered the refractory capacity of the ceramic material. Conversely, the iron oxide content may be a reflection of contamination from the furnace charge.

Unfortunately, less can be deduced from the technical ceramics at this site due to the lack of tuyères. Hopefully, the composition of the furnace walls however, can shed some light on the operation of the smelts at Rukomero.

Metallurgical Analyses

Macro-Descriptions

The only slag blocks that were found at Rukomero were those excavated from the two furnace pits. Three blocks were excavated from each pit; in both pits the morphology of the three slag blocks followed a similar pattern. The uppermost blocks were the smallest, and were irregular in shape (Figure 6.86); the middle blocks were the largest and most amorphous, with flow structure indicative of dripping down through the furnace (Figure 6.87); the lowest blocks in each furnace pit had flattened bases, formed against the furnace bottom (Figure 6.88).

Figure 6.86 Furnace 2, Slag 1

Figure 6.87 Furnace 2, Slag 2

Figure 6.88 Furnace 1, Slag 3

Although not consolidated into a single block (like those seen at Kisamura for example) it is highly likely that the three blocks from each furnace were from a single smelting episode. The fact that the slag block was divided into three may suggest a temporary halt in slag formation at two points during the smelt, perhaps coupled with a high viscosity of slag that hindered the formation of single, coherent blocks, or perhaps a different arrangement of packing materials in the pit.

These six slag blocks were recorded separately, in detail, as at other sites (Table 6.16). As mentioned previously, the bottom slag blocks appeared to have formed pressed against the furnace base, and had a texture that suggested that they had cooled in contact with a sandy surface. In addition to this, sections of the upper blocks were seen to have formed seemingly pressed against the furnace wall – these slag blocks were directly associated with these furnace pits. On areas not defined by contact with the furnace structure, there were solidified flow drips and impressions of small to medium sized grasses or reeds. The slag blocks were dark bluish grey in colour, and were moderately dense.

		Complete	Width a	Width b	Depth	Weight	Samples				
Furnace	Slag #	block?	cms	cms	cms	kg	Top	Middle	Bottom	ED-XRF	OM/SEM-EDS
1	1	Y	42	32	22	25		✔		✔	
	2	Y	30	25	34	32		✔		✔	
	3	Y	42	32	15	28		✔		✔	✔
2	1	Y	22	16	14	7		✔		✔	
	2	Y	40	35	62	43	✔		✔	✔	
	3	Y	38	38	10	18		✔		✔	✔

Table 6.16 Summary of macroscopic information recorded for the slag blocks from Rukomero

On cutting during sample preparation, the slag samples were found to be relatively porous, with air bubbles and plant impressions throughout. The slag from Furnace 1 had particularly high levels of corrosion. Some areas of the slag seemed to have fragments of unreduced ore adhering to them.

Further fragments of unreduced ore were excavated from within both of these furnaces: three from Furnace 1 (Figure 6.89) and seven from Furnace 2 (Figure 6.90). These tended to measure a few cubic centimetres, and were dark purplish black and often cracked. These varied considerably in quartz content, suggesting that they had not been sorted thoroughly before inclusion in the smelt, or alternatively, that these were the discarded fragments that were only thrown into to the furnace after the smelt. It is also surprising that there were so many of such a large size. Perhaps the ores used in these furnaces were smelted from fragments of this size that had been pre-roasted to improve permeability to the furnace gases. Several of the fragments had large cracks (*cf.* Figure 6.90) that may support this as a possibility, although these cracks may have formed in the high temperatures during the course of the smelt. Internal cracks, like those seen in roasted limonite ores used in Haya smelting (*cf.* Schmidt 1997: 114) were not however visible through optical microscopy (*cf.* Figure 6.93).

Figure 6.89 Unreduced ore from Furnace 1, Rukomero

Figure 6.90 Unreduced ore from Furnace 2, Rukomero

ANALYSIS

The PED-XRF results, presented in Table 6.15 and reported in full in Appendix S, demonstrate that the slag samples all fell within the range typical for bloomery iron smelting slag. Although the three slag blocks within each furnace were very similar to each other, there was marked variation between furnaces. Alumina (c. 6wt%), silica (c. 35wt%), lime (c. 1wt%), and manganese (c. 3wt%) and cerium (c. 275ppm) oxides were all higher in Furnace 2, coupled with lower readings for iron oxide (c. 52wt%). Iron oxide content was much higher in the slag blocks from Furnace 1 at approximately 63wt%. Barium (c. 4000ppm), cobalt (c. 400ppm) and neodymium (c. 220ppm) oxides were also higher in these samples. The ratio of alumina to silica in the slag samples from both furnaces averaged at 1:6.

To examine variation within these slag blocks, the coefficients of variation were calculated for all slag blocks together, as well as for the samples from each furnace separately (Figure 6.91). This confirmed that most variation was polarised between the two furnace remains – when considered separately, the CVs tended to drop considerably.

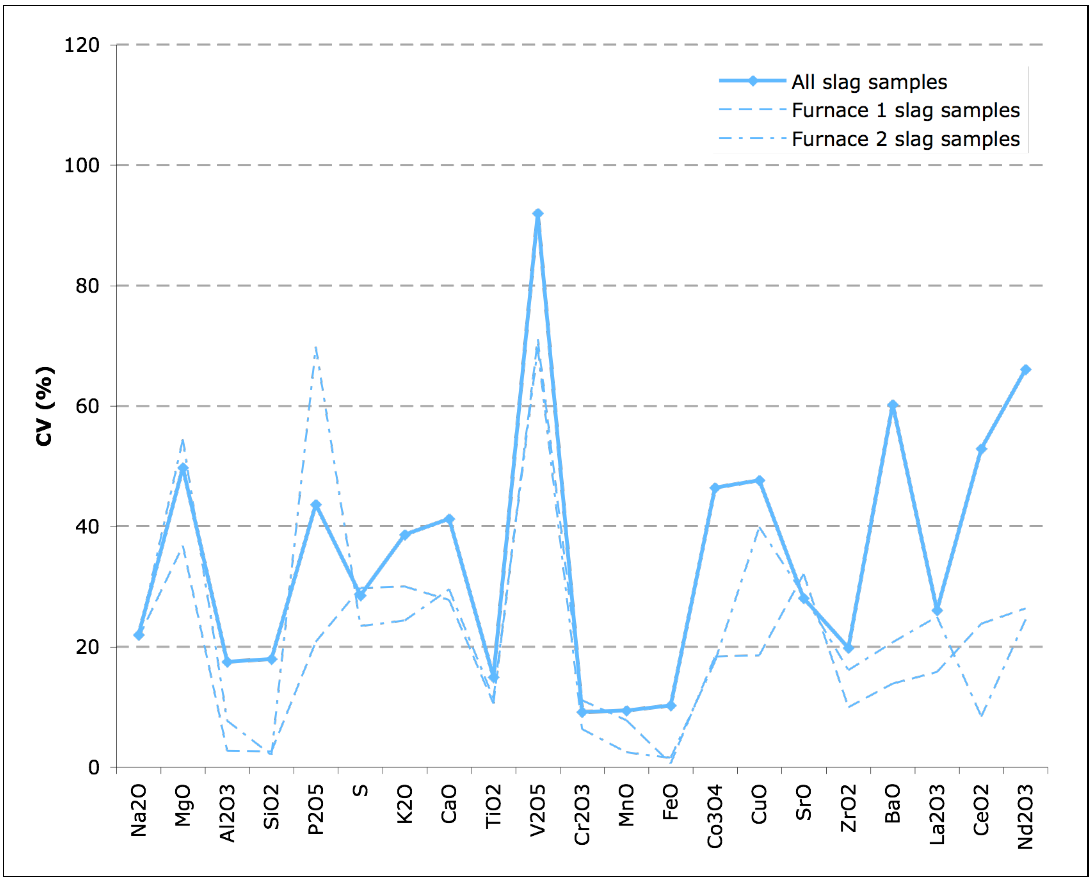


Figure 6.91 Coefficients of variation for all compounds in the sampled slag blocks from Rukomero, calculated from PED-XRF data normalised to 100%

One sample from each furnace (F1S3M, F2S3M) was examined microscopically and with SEM-EDS. The sample from Furnace 1 was porous, but also very homogeneous and showed large, blocky fayalite crystals, consistent with the large furnace pit within which this slag would have slowly cooled. The fayalite was the dominant phase covering over 80% of the sample area (Figure 6.92), and the SEM-EDS analysis showed that it contained up to 1wt% lime and up to approximately 3wt% manganese oxide.

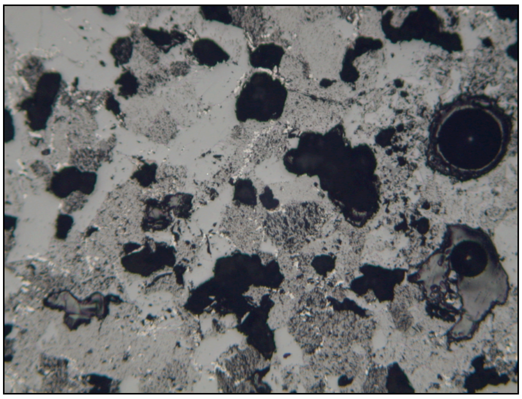


Figure 6.92 Photomicrograph of sample F1S3M, Rukomero, showing extensive porosity (black) and blocky fayalite (mid grey). Image width ≈ 2mm; PPL

Very difficult to see optically (but easier to see with the SEM backscattered electron imaging) was the presence of hercynite (with traces of titania and manganese oxide) throughout the sample. This phase comprised only 7area% of the sample, similar in proportion to the small but dendritic wüstite that was also apparent (Figure 6.93). Eutectic wüstite was also present exsolving out of the glassy matrix. The wüstite itself was found to contain traces (>1wt% each) of alumina, silica, titania and manganese oxide. There was very little glassy matrix, which SEM-EDS analysis found to be approaching the composition of leucite (with an additional 5wt% FeO and 4wt% BaO), and it covered only about 2area%. Approximately 1area% comprised droplets of iron metal dispersed across the sample.

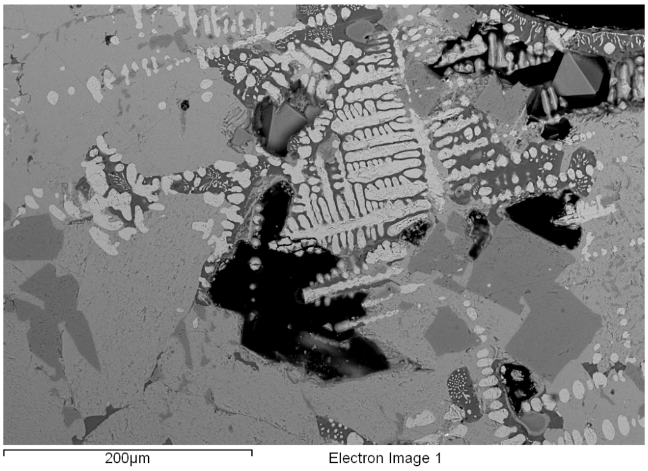


Figure 6.93 BSE image of sample F1S3M, Rukomero, showing dendritic wüstite (light grey), fayalite (mid grey) and hercynite (dark mid grey). Darkest grey is glassy matrix (very limited in extent, see bottom left hand corner of image), with eutectic wüstite. Porosity is black

In contrast, the sample from Furnace 2 was dominated almost entirely by lathes of fayalite in a light grey (under PPL) glassy matrix (Figure 6.94). There were no hercynitic phases apparent, and neither was there any wüstite present. This corresponds with the much lower iron oxide levels in the bulk chemical analyses for this sample. Instead, very fine and feathery fayalite was observed exsolving from the matrix in this sample (Figure 6.95). This sample was also much less porous. Very rare droplets of iron were present, though these covered less than 1% of the sample area.

Interestingly, considering the higher lime contents of the Furnace 2 samples as a whole, there was very little lime present in the fayalite analyses (>1wt%), although there was approximately 5wt% manganese oxide within this phase. The glassy matrix contained approximately 20wt% alumina, 45wt% silica and 24wt% iron oxide. A significant amount of lime (c. 5wt%) was also present, and the matrix was also seen to be acting as a reservoir for phosphate (c. 0.5wt%) and potash (c. 2wt%), in addition to traces of titania and manganese oxide.

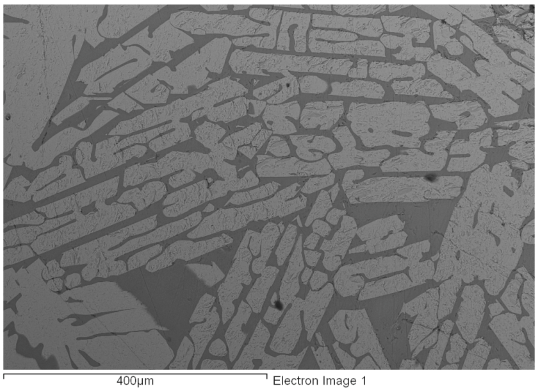


Figure 6.94 BSE image of sample F2S3M, Rukomero showing lathes of fayalite (light grey) in a glassy matrix (mid grey)

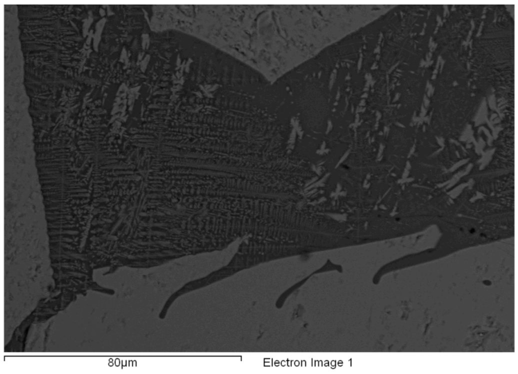


Figure 6.95 BSE image of sample F2S3M, Rukomero, showing feathery fayalite exsolving from the glassy matrix

The two ore samples that were examined microscopically – again, one from each furnace – appeared very similar structurally. They both presented greyish bands under PPL, which appeared bluish under XPL, and approximately 15area% quartz (Figure 6.96). The samples were strongly magnetic and contained up to 0.1wt% cobalt oxide, which may have contributed to the blue colouring, and which would account for the levels of cobalt oxide in the slag samples from this site. It is possible that these samples are banded haematite, magnetised through heating in the furnace (Ineson 1989: 117; Nesse 2004: 304).

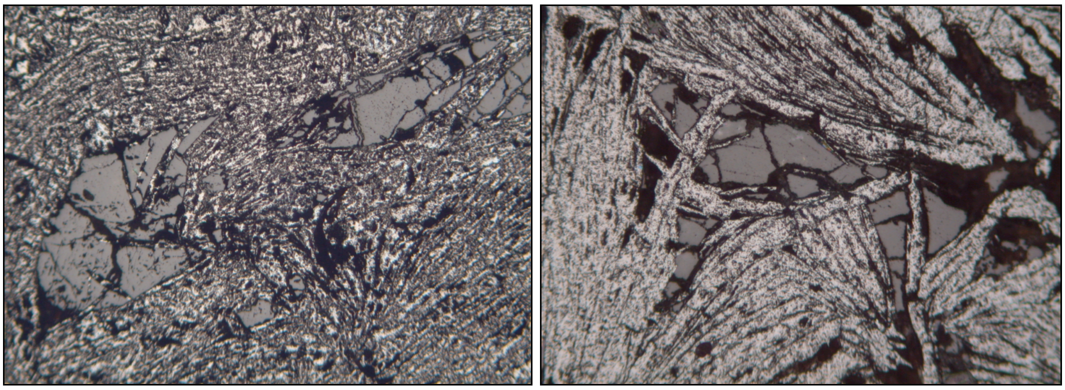


Figure 6.96 Photomicrographs showing ore samples from Furnace 1 (left, image width ≈ 2mm, PPL) and Furnace 2 (right, image width ≈ 1mm, PPL)

SEM-EDS area analyses of the ore sample from Furnace 1, away from quartz grains, revealed a matrix of approximately 98wt% iron oxide (reported as FeO, but most likely Fe_2O_3), with approximately 0.5wt% of alumina and phosphate and just over 1wt% silica. Ill-defined areas of enriched alumina (of up to 13wt%) were visible in the BSE as slightly darker grey patches, but these were very limited in size and frequency. However, they do offer an explanation as to the higher levels of alumina in the bulk analysis of the Furnace 1 ore sample.

DISCUSSION AND SUMMARY

It is perhaps important to note that the two sets of slag remains from each furnace differ in chemical composition in several significant compounds – cobalt, barium and neodymium oxides are higher in Furnace 1; alumina, silica, lime and cerium oxide are higher in Furnace 2. These differences seem to have had considerable associations with the amount of iron oxide remaining in the slag, averaging 63% in Furnace 1 and 52% in Furnace 2.

Once again, it appears feasible that the ore fragments excavated from the furnaces at Rukomero were not entirely representative of the full furnace charge in these instances. Several minor and trace compounds present in the slag fail to be explained by the bulk chemistry of the ore samples. The compounds seen in previous sites to be repeatedly associated with a manganese-rich material, most particularly barium and neodymium oxides, but also copper oxide, zirconia, alumina and lime, are missing from these ore samples although they are present – in varying quantities – in the Rukomero slag. Nevertheless, levels of manganese oxide remain low relative to other sites, as does zirconia and also alumina. Other scenarios are also possible, namely the contribution of these compounds via either technical ceramics or fuel ash. However, investigating these disparities using statistical manipulation would be troublesome due to the small number of samples, and as such, a scenario whereby a second manganese-rich material was also being used in Rukomero has little evidence to support it. To try and extract any further information from these slag samples, they were plotted on a ternary phase diagram (Figure 6.97).

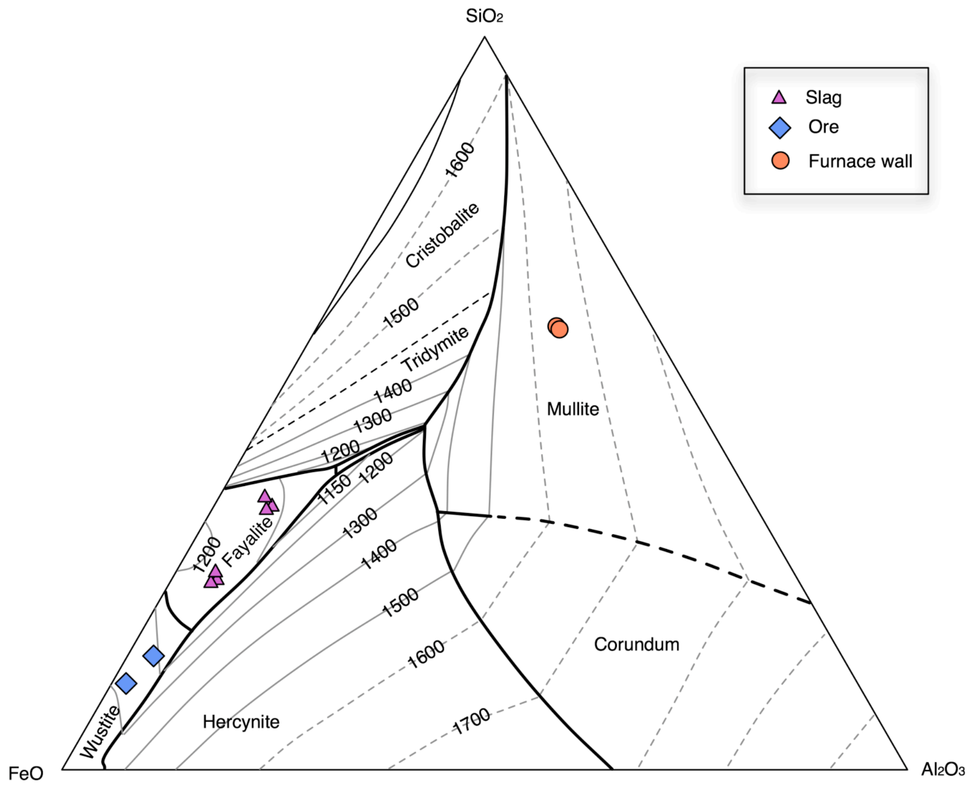


Figure 6.97 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO, with plots for all samples from Rukomero (phase diagram taken from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%; slag samples are plotted in terms of Al_2O_3+TiO2 – SiO_2 – FeO+MnO+CaO

As would be expected from the optical microscopy, these slag samples all fell squarely within the fayalite section of the diagram, and all would appear to have formed at a minimum temperature of between 1150 and 1200°C. The position of the samples from Furnace 2 closer to Optimum 1 (Rehren *et al.* 2007) may indicate a greater contribution from either the technical ceramics or the fuel ash that might explain the raised levels of lime and other compounds in these samples, or simply a more efficient smelt resulting in less iron oxide going into the slag.

Overall, the slags plot away from the fayalite/hercynite trough compared to the other sites, highlighting a relatively lower alumina to silica ratio, which indicates a probable lower ceramic contribution to the melt in these smelting episodes.

In summary, there is relatively little that can be determined from the analyses of the smelting remains at Rukomero, due to the lack of tuyères and the relatively small number of slag blocks. However, the furnaces at this site turned out to be the deepest and largest that were excavated within the central Mwenge region. The size of these furnaces may be one reason why so much unreduced ore survived in the furnace pits rather than becoming incorporated into the melt: within a large furnace, localised variation in reducing atmosphere and temperature must be expected. Due to this, the unreduced ore has provided an opportunity to see that once again a second manganese-rich material may have been used in these smelts, but unfortunately it is not possible to confirm or refute this hypothesis due to a lack of supporting data.

PART FOUR: INITIAL SUMMARY AND DISCUSSION, LATER MWENGE SITES

By now, all of the sites analysed from the central Mwenge region have been reported. A full examination and discussion of the entirety of this new body of data will be presented in Chapter 7. However, it is necessary first to summarise here the findings presented in this chapter.

Once again, the slag that has been encountered is typical of bloomery iron smelting, although at these sites, as at the earlier sites, there is again evidence for localised variation. At Kirongo, it is likely that a tightly controlled – and highly repeatable – technology was being undertaken, using a number of ores, at least one with a high manganese oxide content. At Kisamura, approximately eight kilometres to the southeast, similarly shaped slag blocks were in evidence, and this, alongside broad similarities in bulk compositions hints that a similar technological procedure was being followed at this site. A smaller body of data from Rukomero limited the conclusions that could be drawn about that site, but it was apparent that the smelting at this site, further removed from the central Mwenge sites in terms of landscape if not in distance, was slightly different. Deeper pit furnaces than seen elsewhere in Mwenge seemed to have an effect on the shape of the resulting slag forms, and the slag was less enriched with manganese oxide. With rich ores, the low lime and manganese oxide levels of these systems appear to have had a negative effect on the reduction efficiency of the smelts at Rukomero, with relatively high levels of iron oxide remaining in the slag, although whether this was concerning to those smelters is another matter.

No further tangible evidence for ritual activity (in the form of pits under furnaces or the preservation of 'medicines') was directly associated with the excavated furnaces (though it might be intimated by the addition of an Mn-rich substance and the intriguing deposition of the panga at Kisamura), although the repetition of the use of *Musa* species at Kisamura (paralleled with that first noted on the manganese-rich slags at Mirongo) is also suggestive. This will also be further discussed in Chapter 7.

The furnace structures at these three sites also displayed a relatively high level of variation. Those at Rukomero were deeper and larger than generally seen in the region, whereas the furnace at Kirongo was of a medium size. The furnace at Kisamura was unique to this study, potentially comprising a very shallow furnace pit and built up furnace walls. Whether this furnace, and others like it, would have produced the large slag blocks found at this site is ultimately hard to tell, but it seems unlikely.

When plotted onto a ternary phase diagram (Figure 6.98), most of the slag samples from all three sites grouped very closely together, although several slag samples from

Kirongo and the samples from Furnace 2 at Rukomero plot closer to Optimum 1. Nevertheless, they fit within a smaller compositional range than the sites considered in the preceding chapter, which might indicate a greater degree of regulation in smelting procedure by this time.

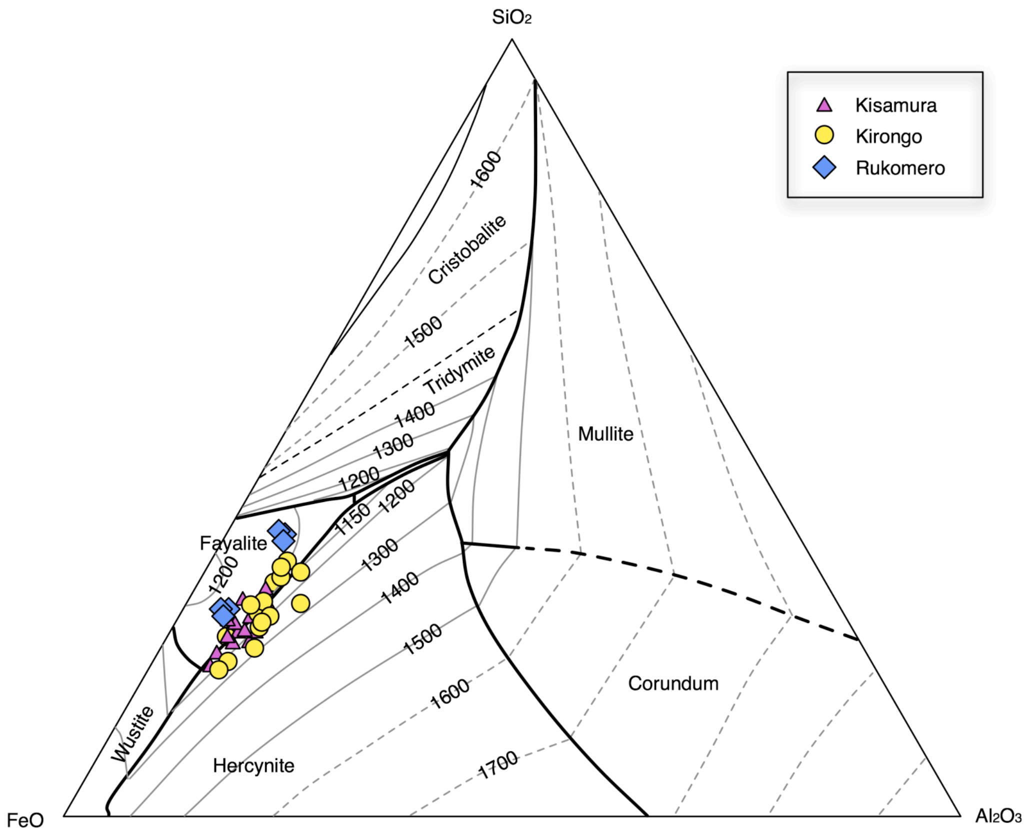


Figure 6.98 Ternary phase diagram showing system Al_2O_3-SiO_2-FeO , with plots for all slag samples from Kirongo, Kisamura and Rukomero in terms of Al_2O_3+TiO_2 – SiO_2 – FeO+CaO+MnO (phase diagram adapted from Slag Atlas 1995). Calculated from PED-XRF data normalised to 100%

The possibility of any further relationships between the sites was investigated using principal component analysis (Figure 6.99, and Appendix T). As would be expected, the samples from Rukomero – the only samples that contained detectable levels of cobalt oxide – were further removed from the other sites' samples. The samples from Kirongo and Kisamura grouped more closely together, sharing broad compositional similarities, but were still separated along PC2. Their compositions are not similar enough to suggest an identical smelting system in these instances, but might suggest a similar technological approach to raw material selection and use.

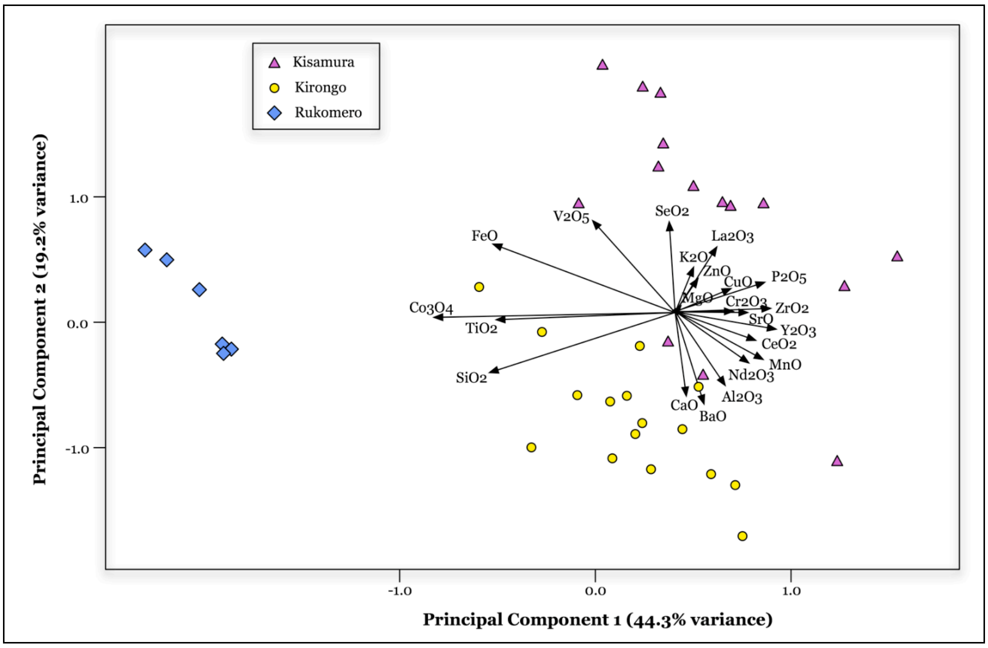


Figure 6.99 Graph of all later Mwenge slag samples in principal component space (PC1 vs. PC2)

The relative paucity of tuyère remains at these three sites is also worthy of note. Two sites bore no tuyères whatsoever; the final one – Kisamura – had very few and those that were present could not be directly linked with the furnace or slag remains. There are several explanations that might account for this absence. Firstly, it is possible that only very few tuyères were used per furnace in these technologies, or secondly, that the used tuyères were re-used for other purposes, perhaps as grog for future pottery or even as a flux for smelting or smithing. Lastly, it is not feasible to rule out the possibility that no tuyères were used in these smelts, however, this would require very specific requirements of positional aspect and furnace construction, and is a technology that has not been documented in this region either in the recent or distant past.

To summarise, the smelting that was carried out at these sites dated to the later kingdom period seems to be related to a greater degree of repeatability and standardisation. The role of manganese-rich materials within these smelting systems continues as a theme (as does grog tempering), emphasising the role that the recent ethnoarchaeological work by Terry Childs could play in understanding the smelting technologies of the more distant past in Mwenge – a topic to be discussed in depth in Chapter 7.

CHAPTER 7

TECHNOLOGICAL RECONSTRUCTIONS
WIDER DISCUSSION AND INTERPRETATION

Now that the archaeological and analytical data for all of the sites have been presented, it is possible to consider this new dataset in more detail, alongside the available ethnographic material. Following a brief overview of all the sites, this chapter will present a more detailed analysis of the technical components of the smelting remains under examination, as well as the social and economic contexts within which these smelters operated, thereby building up a more thorough picture of these technologies on a local level. In the next chapter, the relationship of these technologies to the wider social and political arenas that they operated within – those of western Uganda and the Great Lakes region – will be considered.

PART ONE: TECHNICAL PARAMETERS

As presented in the preceding chapters, all of the slag and furnace remains were found to originate from bloomery iron smelting. An overview of some of the information recovered from these remains – through archaeological and analytical procedures – is presented below in Tables 7.1 and 7.2.

Several themes recurred throughout the sample set from Mwenge. These included the use of pit furnaces packed with plant remains (occasionally *Musa* spp.), the use of grog temper in technical ceramics and the presence of elevated levels of manganese oxide within the smelting systems. These themes, their possible socio-technological foundations and their technical implications, will be explored in more detail below.

	KTR	MNG 1	MNG 2	RGB	KRG	KSM	RKM
Average weight of complete slag blocks (number of blocks averaged)	78kg (1)	20kg (5)	15kg (5)	8kg (5)	25kg (5)	36kg (11)	26kg (6)
Banana impressions?	No	No	Yes	No	No	Yes	No
Concave slag blocks?	No	No	Yes	No	No	No	No
Furnace dimensions	30cm deep, 50cm diameter	35cm deep, 75cm diameter	?	40cm deep, 70cm diameter	30cm deep, 50cm diameter	c. 15cm deep, 70cm-1m in diameter	60cm deep, 70cm diameter
Tuyères present?	Yes	Yes	Yes	Yes	No	Yes	No
Grog temper?	Yes	Yes	Yes	Yes	(in domestic pottery)	Yes	?
Estimated bloating temperature of ceramics	1200-1250°C	1250°C	1250°C	1200°C	?	over 1200°C	?
High MnO slag?	No	No	Yes	No	Yes	Yes	No
High P_2O_5 slag?	Yes	Yes	No	Yes	No	Yes	No
Possible quartz flux?	Yes	No	No	No	Yes	No	No
Estimated minimum liquidus temperature of slag	1100-1200°C	1100-1300°C	1100-1300°C	1100-1200°C	1100-1300°C	1100-1300°C	1150-1200°C

Table 7.1 Summary of elements of technological information for all excavated smelting sites from Mwenge

	Major and minor compounds												
	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
Kyakaturi average	0.23	0.27	7.34	30.21	1.47	0.07	1.42	2.72	0.42	0.04	0.11	0.93	53.54
Mirongo Group 1 average	0.16	0.17	5.75	20.07	2.03	0.19	1.19	1.51	0.41	0.05	0.12	2.47	62.38
Mirongo Group 2 average	0.16	0.87	8.30	30.41	1.27	0.13	1.60	2.83	/	0.02	0.10	10.91	40.41
Rugombe average	0.25	0.19	6.61	21.02	2.14	0.15	1.03	1.21	0.28	0.04	0.08	2.79	60.51
Kirongo average	0.30	0.28	7.98	24.75	1.24	0.09	1.37	2.59	0.12	0.00	0.10	8.09	49.37
Kisamura average	0.25	0.32	7.07	21.93	1.68	0.14	1.82	1.65	0.13	0.03	0.10	8.19	52.75
Rukomero average	0.22	0.13	5.21	30.52	0.05	0.06	0.56	1.03	0.19	0.01	0.02	2.98	57.73

	Trace compounds											
	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	SeO_2 ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm
Kyakaturi average	658	/	286	57	/	399	59	433	1944	454	573	247
Mirongo Group 1 average	550	22	390	/	/	413	66	1069	2709	1107	793	573
Mirongo Group 2 average	/	17	228	/	/	558	80	410	17921	1199	961	1803
Rugombe average	467	/	280	40	/	820	70	872	5789	996	1233	799
Kirongo average	/	/	197	/	/	358	89	638	13105	318	1007	792
Kisamura average	/	/	281	23	50	419	104	770	7677	850	1060	807
Rukomero average	279	/	47	/	/	115	/	101	2449	102	188	145

Table 7.2 Averaged slag compositions from all sites in Mwenge (PED-XRF)

MANGANESE AND IRON: MALE AND FEMALE 'ORES'?

One of the most interesting threads running through much of the data presented in the preceding chapters has been the elevated levels of manganese oxide in many of the slag samples from Mwenge. Three of the sites presented in Chapters 5 and 6 bore slag blocks with significant levels of manganese oxide (i.e. on average, over 8wt%). These sites (or in the case of Mirongo, clusters within sites) were Mirongo Group 2, Kirongo and Kisamura. As introduced in the earlier presentations of these sites, the possibility was raised that high manganese oxide levels were the result of using a manganese-rich substance in addition to one (or hypothetically more) iron-rich ore(s).

There is considerable ethnohistoric evidence to suggest that this is a distinct possibility in the region. Of the three accounts of recent smelting in western Uganda – Roscoe (1923), Buchanan (1974a) and Childs (1998a) – all either imply or state the use of a combination of ores. Roscoe's description of Nyoro smelting presents genderised ores: a 'female' ore that was described as red and soft; and a 'male' ore, black and hard. In Childs' account of smelting in Mwenge (1998: 131), two similar ores were combined as they were dried prior to the smelt, allowing them to 'befriend' or 'embrace', lexicologically imbuing these materials with connotations of gender and sexual reproduction. Cline (1937: 117) suggests that the red, soft, female ore might be a description of a haematite iron ore and that the hard, black male ore might represent a typical magnetite ore, yet it is feasible that the latter might constitute a manganese mineral in certain circumstances, local geology permitting (to be discussed later). As such, the manganese oxide levels of these slag blocks warrant further investigation and discussion, and may provide archaeological time-depth to an otherwise ethnoarchaeologically-documented phenomenon.

In particular, three questions arise from the elevated manganese oxide levels of these slag samples:

- What technical impacts would such levels of manganese oxide have on these smelting systems?

- Was a manganese-rich material added deliberately and separately to the smelts in addition to an iron-rich ore?
- Could this constitute the male and female ores suggested by the ethnographic literature?

Technical impacts of manganese:

First, the impacts of elevated manganese-oxide levels upon the operation of the smelts in question will be addressed. Many European iron ores (most commonly limonites, goethites and siderites; less frequently haematites and magnetites) are manganiferous, of which there are significant deposits in the UK, Germany, Austria, Scandinavia and Eastern Europe (Tylecote 1962; Rostoker and Bronson 1990: 46). Several noteworthy examples of the smelting of such ores come from these regions. Tylecote (1992: 65) identifies three Roman sites in Austria, Germany and Denmark that bore high-manganese slag (c. 7-17wt% MnO), as well as the use of manganiferous ores in Roman and Medieval Britain and Ireland (1962). Straube (1996) and Cech (2008) describe the famous production of Ferrum Noricum steel using manganese-rich ores in Austria. Buchwald (2003) notes further Scandinavian examples of manganiferous bloomery smelting, with slag inclusions in iron of up to nearly 20wt% manganese. Overall however, MnO-rich slag (defined by Pleiner (2000: 252) as exceeding 3.5wt%) remains relatively rare in the archaeological record (Hauptmann 2007).

Rostoker and Bronson (1990: 46) propose that manganiferous iron ores are far less common in sub-Saharan Africa, with only “scattered occurrences” of high manganese haematites, whereas manganiferous limonites and siderites are “almost entirely absent”. They postulate that this may reflect the incomplete geological knowledge of the continent, but go on to reiterate “manganese-containing iron ores are less common in tropical and semitropical regions”. Seemingly in keeping with this, Cline (1937: 43) makes only one mention of iron production in Africa with a manganese-rich ore. This is the smelting in Aoumbo, southern Gabon, where ore with 8wt% manganese oxide and almost 70wt% iron oxide was smelted.

Nevertheless, the presence of manganese oxide in significant quantities within iron smelting systems has been documented (both archaeologically and experimentally) as having a beneficial effect in terms of the 'efficiency of reduction' of smelts, maximising the return produced by a smelt as compared to the effort put in (*cf.* Charlton *et al.* 2010). This overall effect is the result of a combination of factors regarding how manganese behaves within and impacts upon a smelt, with possible consequences for the iron that is produced as well.

Primarily, manganese oxide acts as an effective fluxing agent for silica-based gangue. It has a considerable effect on reducing the melting temperature of typical bloomery slag, encouraging a fluid slag that separates easily from the bloom. Furthermore, due to the chemical similarities manganese bears with iron – which it neighbours in the periodic table – it can replace iron to react with silica, forming knebelite – $(Mn,Fe)_2SiO_4$ – rather than fayalite. This results in more free iron oxides within a given smelt that can reduce to metallic iron, increasing the percentage of metal that can be recovered from an iron ore (Tylecote 1962: 191; Rostoker and Bronson 1990: 19; Charlton *et al.* 2010). This effect was frequently observed in the microanalyses of the olivines of manganese-rich slag samples presented in Chapters 5 and 6, where levels of manganese oxide ranged between 15 and 30wt%.

When highly generalised hypothetical mass-balances were calculated from two theoretical ore mixes – one Fe-rich, one mixed Fe-Mn – this difference in maximum possible yield was evident and dramatic (Figures 7.1, 7.2 and 7.3): a significant factor (although only one of many) if considering the economic value of adding manganese-rich ore. These very basic mass balances assume that all silica is to be bound with either iron or iron and manganese to form fayalite or knebelite (and equally, that all – or most – manganese oxide binds with silica in the knebelite), and that all remaining iron oxides reduce to iron metal in the bloom. The ratio of iron to manganese in the knebelite can vary considerably, and as such two alternative Mn-Fe models were considered: one that mirrored the knebelite composition at Mirongo Group 2 – $(Mn_1Fe_1)_2SiO_4$ (Figure 7.4); and one that mirrored that at Kisamura and Kirongo $(Fe_{1.5}Mn_{0.5})_2SiO_4$ (Figure 7.5). Other inputs and outputs are not accounted for.

Although these systems are idealistic in real terms, they do serve to demonstrate the potential maximum proportion of iron 'saved' with the addition of manganese oxide, and aids comparison between these three scenarios.

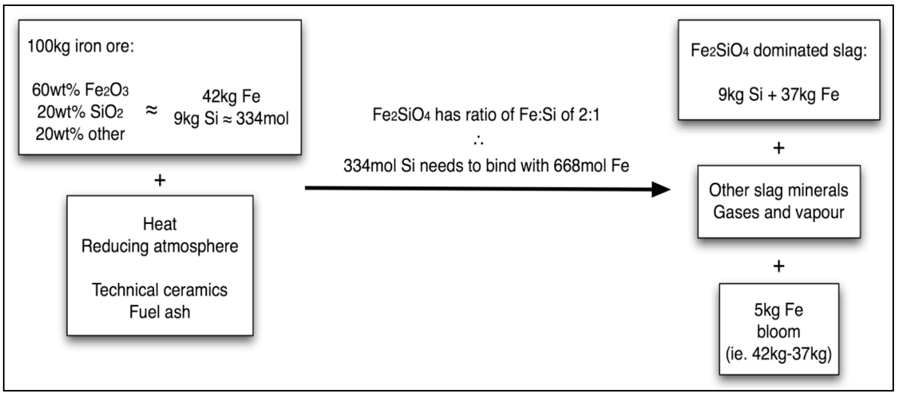


Figure 7.1 Hypothetical mass balance to estimate the potential maximum yield of iron from an ore with 60wt% iron oxides and 20wt% silica

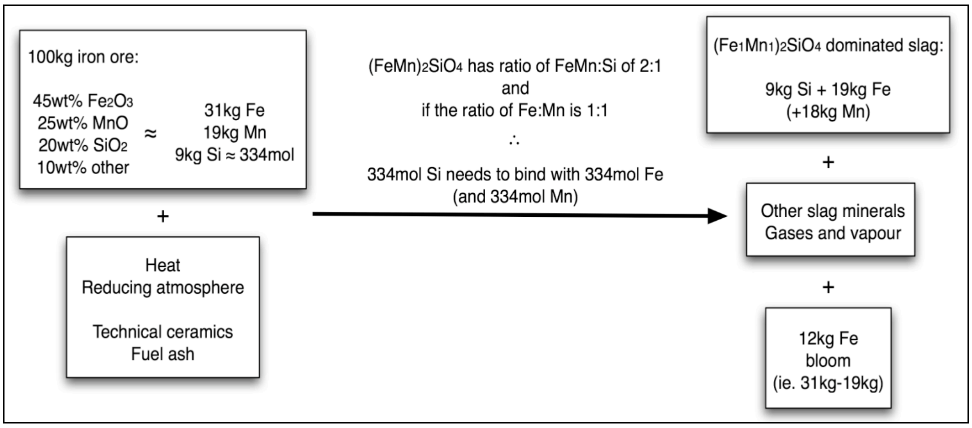


Figure 7.2 Hypothetical mass balance to estimate the potential maximum yield of iron from an ore with 45wt% iron oxides, 25wt% manganese oxide and 20wt% silica, resulting in knebelite with an Fe:Mn ratio of 1:1

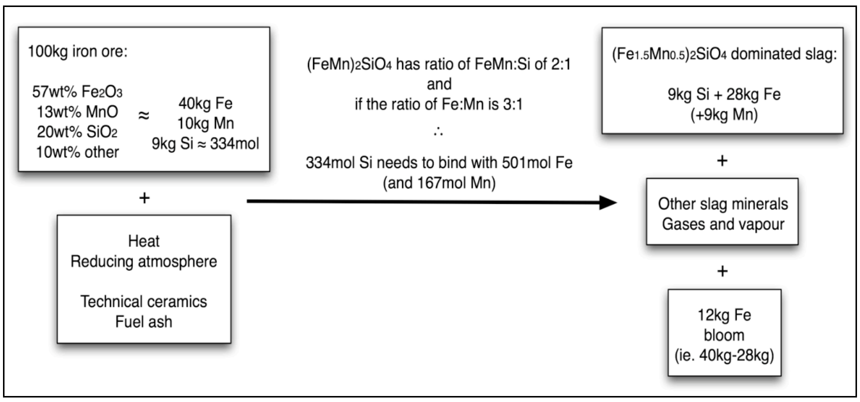


Figure 7.3 Hypothetical mass balance to estimate the potential maximum yield of iron from an ore with 57wt% iron oxides, 13wt% manganese oxide and 20wt% silica, resulting in knebelite with an Fe:Mn ratio of 3:1

When calculated, the proportion of iron recovered from the iron ore rose from 12% in the ore with 60wt% iron oxides (i.e. a 5kg bloom was recovered from a possible 42kg of available Fe in the original ore) to 39% and 30% in the examples with manganese oxide present in the ore mix. This is a considerable difference in potential yield, which is typically between 15 and 25% (David *et al.* 1989: 196).

However, if manganese is enriched in an ore at the *expense* of iron oxides (rather than at the expense of alumina or silica), then no benefit in terms of yield will be realised, as less iron oxide will be available for reduction (although the manganese-rich slag will *appear* leaner). On this basis, manganese is especially beneficial to a smelt if added separately, in addition to an iron-rich ore.

Nevertheless, several authors have also suggested that a significant presence of manganese oxide within a smelting system also has a positive effect on the operational parameters of a smelt. Experiments by Peter Crew with a mixed ore of iron (60wt%) and manganese oxides (10wt%), demonstrated its highly reducible nature. Using a fuel to ore ratio of 2:1, this manganese-iron mix was reduced very quickly to produce a bloom containing cast iron (Crew and Charlton 2007). It was suggested that a much lower fuel to ore ratio, perhaps as low as 1:2, would have been sufficient to produce bloomery iron, thus lowering demands on charcoal production per volume of iron produced. Although discussing copper smelting, Hauptmann (2007: 185) also states that manganese-rich silicates appear to have an increased resistance to fluctuations in the atmosphere of a furnace, positing that as long as the temperature is maintained at between 1150 and 1200˚C smelts are more likely to be successful even if the furnace atmosphere does not remain constant. These attributes mean that the extraction of iron metal through bloomery smelting is improved with the presence of manganese in the system, both in terms of reducing the risk of a smelt 'freezing' as well as increasing the yield from a given iron ore.

A further consideration is the effect that manganese oxide might have on the resulting iron metal. Manganese as an alloying constituent with iron is known to have several advantages: first, it encourages the uptake of carbon by the iron; second, it increases the hardenability of the carburized iron; third, it promotes the uptake of nitrogen to the iron – a lesser alloying agent that also increases strength, hardness, hardenability and resistance to corrosion; finally, it removes sulphur, thereby reducing hot shortness (Rostoker and Bronson 1990: 99; Charlton 2007: 106-108).

A bloomery furnace operating at a minimum temperature for iron smelting will theoretically *not* reduce the chemically stable manganese oxide to manganese, a process that requires a temperature of above 1400°C with a CO/CO_2 ratio of 10^4 (Alcock 1976: 199-200; Rostoker and Bronson 1990: 19; Charlton 2007: 106). However, if conditions are exceptionally reducing, small amounts of manganese are reduced and partition to the metal, especially when cast iron is produced (whether accidentally or intentionally), and when conducive conditions are amplified at localised hot spots (Rostoker and Bronson 1990: 100):

> "What is very noticeable is the uniformly low manganese content [of analysed Roman period iron objects from the UK]. This element, although present in the ores in many cases, is not reduced during the normal smelting process and finds its way almost exclusively into the slags. <u>It is present in both the cast irons, showing that they have been made under abnormal conditions</u>".
>
> (Tylecote 1962: 191, emphasis added)

Further examples do exist of manganese-enriched iron produced from lower-temperature bloomery smelting. Rostoker and Bronson (1990: 99-100) suggest that such partitioning of manganese into bloomery iron, even when smelted at relatively low temperatures, is the result of the absorption of manganese vapour. Manganese has a vapour pressure of 121Pa at a temperature of 1244°C, and this vapour might feasibly be absorbed by metallic iron. Although this is unlikely to result in a significant transfer of manganese to the iron, it could account for the low levels of manganese (<0.1wt%) seen in some archaeological samples of ironwork, such as the products of some early Roman and Hallstatt or La Tène bloomery smelting in modern Austria and Sweden (Coghlan 1977: 38; Rostoker and Bronson 1990: 20). Equally however, bloomery smelting with moderately enriched Mn-Fe ores can also result in low manganese iron (e.g. Todd and Charles 1978: 83).

However, Alcock (1976: 200-201) suggests that any vaporised manganese would either be re-oxidised very quickly in the lower temperatures higher up in the furnace or be blown out of the furnace "as fine particles in the discharge gases". Instead, he suggests "the main reduction path is the direct reduction of MnO from a liquid slag through contact with solid coke particles or carbon-saturated liquid iron droplets"; dramatically increasing the reducing atmosphere would optimise this process. Although he is talking specifically about blast furnaces, it is feasible that limited, localised, carbon-contact manganese oxide reduction may also occur within a bloomery furnace, if temperature and reducing atmosphere are both high enough. The presence of foils of reduced iron within the Mwenge slag samples (*cf.* for example Figures 5.58 and 6.63) is testament to the fact that localised pockets of such reducing conditions do occur in these furnace environments.

Taking all this into consideration, it appears that within bloomery furnaces operating at temperatures not too far above the liquidus minimum (for the sake of argument, not below 1300˚C) it is more likely that manganese oxide would *not* reduce and partition to the iron metal in significant quantities, and would consequently not impart a tangible effect on the attributes of the bloom and workable iron. However, Hauptmann (2007: 235) also mentions the relationship between the smelting of such manganese-rich ores and "a stronger carburization of the iron" by proxy, causing what he considers to be "a distinct improvement in the material". The production of Ferrum Noricum steel at Hüttenberger Erzberg in Austria has been linked to the exploitation of manganiferous limonite and siderite ores (Preßlinger 2008; Truffaut 2008). It seems that the presence of manganese *can* encourage a higher carbon-content of the resulting iron.

Without any analyses of bloom fragments or metal products from this region it is difficult to say whether the smelting of manganese-rich ores (or ore mixes) in this region would have made an impact on the resulting metal, or indeed if this was a purposeful aim of the smelters in Mwenge and an 'improvement' as such.

Nevertheless, it is a significant consideration to bear in mind[1], and will be relevant to later discussions of the ethnographic data from Mwenge. Spot analyses of wüstite in slag samples from sites with manganese-rich slag averaged between 5 and 10wt% MnO. Analyses of droplets of iron within the slag however, were unable to detect any manganese. More likely is the recognition that manganese-rich iron ores provided an improved yield of iron metal, with slightly more flexible operating parameters and reduced fuel requirements. This discussion becomes more relevant when considering some of the ethnoarchaeological data from Mwenge presented later in this chapter.

The addition of manganese as a separate fluxing agent:

The next question was to examine the means by which manganese was introduced into the furnace: was it added deliberately as a flux, in recognition of the benefits described above, or did it naturally occur in association with an iron ore? The presence of elevated manganese oxide in slag has tended to be used as a stand-alone argument for the deliberate addition of a separate fluxing agent, although more commonly in relation to copper smelting rather than iron smelting (Hauptmann 2007:181; although see Radivojevic *et al.* 2010 for an example of preferential selection of manganese-rich malachite rather than the addition of a manganese-rich flux). However, this relationship should not be assumed, but instead should be explored as a hypothesis.

One problem in distinguishing between these two possibilities is the natural pairing of manganese and iron in the geological environment: the mineral forms of these elements often occur together in ore bodies (Rostoker and Bronson 1990: 19). Iron ores in sedimentary deposits can be intergrown with manganese ores, effectively producing the qualities of a 'self-fluxing ore'; it is often possible to explain a 'fluxing agent component' as coming from the host rock of the ore itself.

[1] This manganese-rich slag may also prove useful in future provenance studies of iron objects across Uganda. Smelters in Mwenge (and Bunyoro in general) were well respected for their iron, and the goods they produced were traded across the region. Perhaps the high manganese contents of the local ores hold the key to their production of superior iron; slag inclusions in iron objects may indicate the geographic extent of how far this iron was traded (*cf.* Paynter 2006; Blakelock *et al.* 2009).

> "The assessment of whether an ore deposit contains self-fluxing ore requires perspicacity, because highly reactive mixtures of ore and gangue or host rock, which form liquid slag melts at 1200°C without any problems, are quite common", without the use of additional fluxing agents.
>
> (Hauptmann 2007: 250)

In the case of western Uganda, the ethnographic data seem to add suggestive evidence to the proposal of the use of a second (manganese-rich?) material, distinct and separate from the iron ore. However, the manganese oxide levels in the slag samples from all sites are relatively high; does the presence of manganese in particularly high quantities at certain sites reflect the deliberate addition of a separate manganese ore at those sites or just the utilisation of a manganese-enriched part of an Fe-Mn continuum ore body? To examine the hypothesis of the use of two separate 'ores' being used at Mirongo Group 2, Kirongo and Kisamura, a more detailed evaluation of the bulk chemistry of all the slag samples' chemical data was undertaken, to isolate the nature of the charge.

Although there was some variation in the PED-XRF results, the chemical compositions of the slag samples at all sites were remarkably similar (*cf.* Tables 7.3 and 7.4). Aside from manganese oxide, striking variation was only apparent in several trace compounds. Of particular interest was cobalt oxide – this compound was below detection limits in all of the samples with high manganese oxide, contrasting with its consistent presence (averaging approximately 0.05wt%) in all samples with low manganese oxide[2]. Barium, cerium and neodymium oxides also varied considerably between these two groups.

[2] Although the milling may have added cobalt contamination to the slag samples (*cf.* Chapter 4), this would be expected to be comparable and consistent across the dataset.

	Major and minor compounds												
	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
Mirongo Group 2 average	0.19	0.87	8.30	30.41	1.27	0.13	1.60	2.83	/	0.03	0.10	10.91	40.41
Kirongo average	0.30	0.28	7.98	24.75	1.24	0.09	1.37	2.59	0.22	0.02	0.10	8.09	49.37
Kisamura average	0.25	0.32	7.07	21.93	1.68	0.14	1.82	1.65	0.13	0.03	0.10	8.19	52.75
Overall average	**0.26**	**0.39**	**7.66**	**24.52**	**1.42**	**0.11**	**1.59**	**2.25**	**0.18**	**0.03**	**0.10**	**8.59**	**49.29**

	Trace compounds										
	NiO ppm	CuO ppm	ZnO ppm	SeO_2 ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm
Mirongo Group 2 average	17	228	/	/	558	80	410	17921	1199	961	1803
Kirongo average	/	197	/	/	358	89	638	13105	318	1007	792
Kisamura average	/	281	23	50	419	104	770	7677	850	1060	807
Overall average	**17**	**236**	**23**	**50**	**415**	**94**	**654**	**11686**	**677**	**1021**	**962**

Table 7.3 Averaged PED-XRF compositional data for all Mn-rich slag samples from Mirongo, Kirongo and Kisamura, normalised to 100%

	Major and minor compounds												
	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
Kyakaturi average	0.23	0.27	7.34	30.21	1.47	0.07	1.42	2.72	0.42	0.04	0.11	0.93	53.54
Mirongo Group 1 average	0.16	0.17	5.75	20.07	2.03	0.19	1.19	1.51	0.41	0.05	0.12	2.47	62.38
Rugombe average	0.25	0.19	6.61	21.02	2.14	0.15	1.03	1.21	0.28	0.04	0.08	2.79	60.51
Rukomero average	0.22	0.13	5.21	30.52	0.05	0.06	0.56	1.03	0.19	0.01	0.02	2.98	57.73
Overall average	**0.21**	**0.19**	**6.23**	**25.45**	**1.42**	**0.12**	**1.05**	**1.61**	**0.32**	**0.03**	**0.08**	**2.29**	**58.54**

	Trace compounds										
	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm
Kyakaturi average	658	/	286	57	399	59	433	1944	454	573	247
Mirongo Group 1 average	550	22	390	/	413	66	1069	2709	1107	793	573
Rugombe average	467	/	280	40	820	70	872	5789	996	1233	799
Rukomero average	279	/	47	/	115	/	101	2449	102	188	145
Overall average	**489**	**22**	**251**	**48**	**437**	**65**	**619**	**3223**	**665**	**697**	**441**

Table 7.4 Averaged PED-XRF compositional data for all Mn-poor slag samples from Kyakaturi, Mirongo, Rugombe and Rukomero, normalised to 100%

In the manganese-rich samples, alumina was present at about 7 or 8wt%, phosphate at just over 1wt% and lime between 1 and 3wt%. Significant levels of copper oxide and rare earth compounds (La, Ce, Nd) were present, and particularly high levels of barium oxide occurred in all samples. As might be expected, the site with the highest average manganese oxide content (and highest lime content) – Mirongo Group 2 – had the lowest iron oxide content.

Of the four sites (or sub-sites) with slag containing relatively *low* levels of manganese oxide, one – Kyakaturi – contained under 1wt% MnO on average, whereas the other sites contained between 2 and 3wt%. Kyakaturi is geographically further removed from the other sites in central Mwenge; the lack of manganese oxide in these samples may be a reflection of the differential presence of manganese oxide in the local background geology of the area. Alternatively, access to manganese-rich deposits by Kyakaturi smelters may have been restricted. Alumina and silica levels were comparable to the manganese-rich samples, but iron oxide levels were nearly 10wt% higher. Lime contents also tended to be lower in these samples.

Due to the positive effect of manganese oxide (and lime) upon the reduction efficiency of a smelt (as explained above, and evidenced in the iron oxide contents), a direct negative correlation between the level of manganese oxide and the level of iron oxide in any given slag sample is likely. Considering this, the correlation between iron and manganese oxides cannot be used to identify whether or not iron oxide and manganese oxide are coming from the same source i.e. a single ore. Instead, it becomes necessary to explore the chemical groups that are related to these two components, to try and define whether they are associated with particular and separate source ore bodies or if they are chemically and mineralogically related. Principal component analysis was deemed a capable statistical tool with which to assess this effectively.

When factor analysis was applied to all slag samples from Mwenge, titania, vanadium and cobalt oxides correlated strongly with iron oxide. This group had a negative correlation with a second group: that of manganese, barium and neodymium oxides (Table 7.5 and Figure 7.4). These two chemical groupings are likely to indicate the addition of two separate and distinct mineral substances to the smelts, and support the proposition that two ingredients – a manganese ore and an iron ore – were utilised in the manganese-rich smelting systems.

	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V_2O_5	FeO	Co_3O_4	Cr_2O_3	MnO	BaO	Nd_2O_3	CuO	SrO	Y_2O_3	ZrO_2	La_2O_3	CeO_2	
MgO		0.2	0.3	0.1	0.5	0.6	-0.3	-0.1	-0.6	-0.3	0.0	0.4	0.2	0.3	-0.1	0.3	0.1	-0.1	0.2	0.1	MgO
Al_2O_3	0.2		0.3	0.0	0.3	0.4	-0.3	-0.4	-0.7	-0.3	0.2	0.5	0.5	0.3	-0.2	0.0	0.3	-0.1	-0.3	0.2	Al_2O_3
SiO_2	0.3	0.3		-0.5	0.1	0.5	0.1	-0.2	-0.6	0.0	-0.3	-0.1	0.0	-0.1	-0.5	-0.2	-0.3	-0.5	-0.3	-0.3	SiO_2
P_2O_5	0.1	0.0	-0.5		0.2	0.0	0.2	0.4	0.2	0.2	0.2	-0.1	-0.2	0.1	0.4	0.7	0.5	0.7	0.6	0.5	P_2O_5
K_2O	0.5	0.3	0.1	0.2		0.4	-0.2	-0.1	-0.5	-0.3	0.2	0.2	0.1	0.1	-0.1	0.0	0.2	0.0	0.0	0.1	K_2O
CaO	0.6	0.4	0.5	0.0	0.4		0.0	-0.2	-0.7	-0.1	0.0	0.2	0.2	0.1	-0.1	0.3	0.2	-0.1	0.0	0.1	CaO
TiO_2	-0.3	-0.3	0.1	0.2	-0.2	0.0		0.6	0.4	0.8	0.0	-0.8	-0.7	-0.5	0.1	0.0	-0.3	0.1	0.0	-0.3	TiO_2
V_2O_5	-0.1	-0.4	-0.2	0.4	-0.1	-0.2	0.6		0.6	0.7	0.3	-0.6	-0.6	-0.3	0.4	0.2	-0.2	0.3	0.3	-0.1	V_2O_5
FeO	-0.6	-0.7	-0.6	0.2	-0.5	-0.7	0.4	0.6		0.6	0.1	-0.6	-0.6	-0.4	0.4	0.0	-0.3	0.3	0.1	-0.2	FeO
Co_3O_4	-0.3	-0.3	0.0	0.2	-0.3	-0.1	0.8	0.7	0.6		0.2	-0.8	-0.6	-0.4	0.4	0.1	-0.3	0.0	0.1	-0.3	Co_3O_4
Cr_2O_3	0.0	0.2	-0.3	0.2	0.2	0.0	0.0	0.3	0.1	0.2		0.0	0.1	0.1	0.3	-0.1	0.2	0.1	0.0	0.1	Cr_2O_3
MnO	0.4	0.5	-0.1	-0.1	0.2	0.2	-0.8	-0.6	-0.6	-0.8	0.0		0.8	0.6	-0.1	0.0	0.5	0.0	0.1	0.4	MnO
BaO	0.2	0.5	0.0	-0.2	0.1	0.2	-0.7	-0.6	-0.6	-0.6	0.1	0.8		0.8	-0.2	0.0	0.4	0.0	0.1	0.5	BaO
Nd_2O_3	0.3	0.3	-0.1	0.1	0.1	0.1	-0.5	-0.3	-0.4	-0.4	0.1	0.6	0.8		-0.1	0.2	0.5	0.2	0.6	0.6	Nd_2O_3
CuO	-0.1	-0.2	-0.5	0.4	-0.1	-0.1	0.1	0.4	0.4	0.4	0.3	-0.1	-0.2	-0.1		0.3	0.2	0.3	0.2	0.1	CuO
SrO	0.3	0.0	-0.2	0.7	0.0	0.3	0.0	0.2	0.0	0.1	-0.1	0.0	0.0	0.2	0.3		0.4	0.5	0.6	0.5	SrO
Y_2O_3	0.1	0.3	-0.3	0.5	0.2	0.2	-0.3	-0.2	-0.3	-0.3	0.2	0.5	0.4	0.5	0.2	0.4		0.6	0.4	0.7	Y_2O_3
ZrO_2	-0.1	-0.1	-0.5	0.7	0.0	-0.1	0.1	0.3	0.3	0.0	0.1	0.0	0.0	0.2	0.3	0.5	0.6		0.6	0.5	ZrO_2
La_2O_3	0.2	-0.3	-0.3	0.6	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.1	0.1	0.6	0.2	0.6	0.4	0.6		0.5	La_2O_3
CeO_2	0.1	0.2	-0.3	0.5	0.1	0.1	-0.3	-0.1	-0.2	-0.3	0.1	0.4	0.5	0.6	0.1	0.5	0.7	0.5	0.5		CeO_2

Table 7.5 Correlation matrix of all slag samples from Mwenge, generated using SPSS v.17.0 software. Yellow shading indicate positive correlations over 0.6; grey shading indicates negative correlations over -0.6

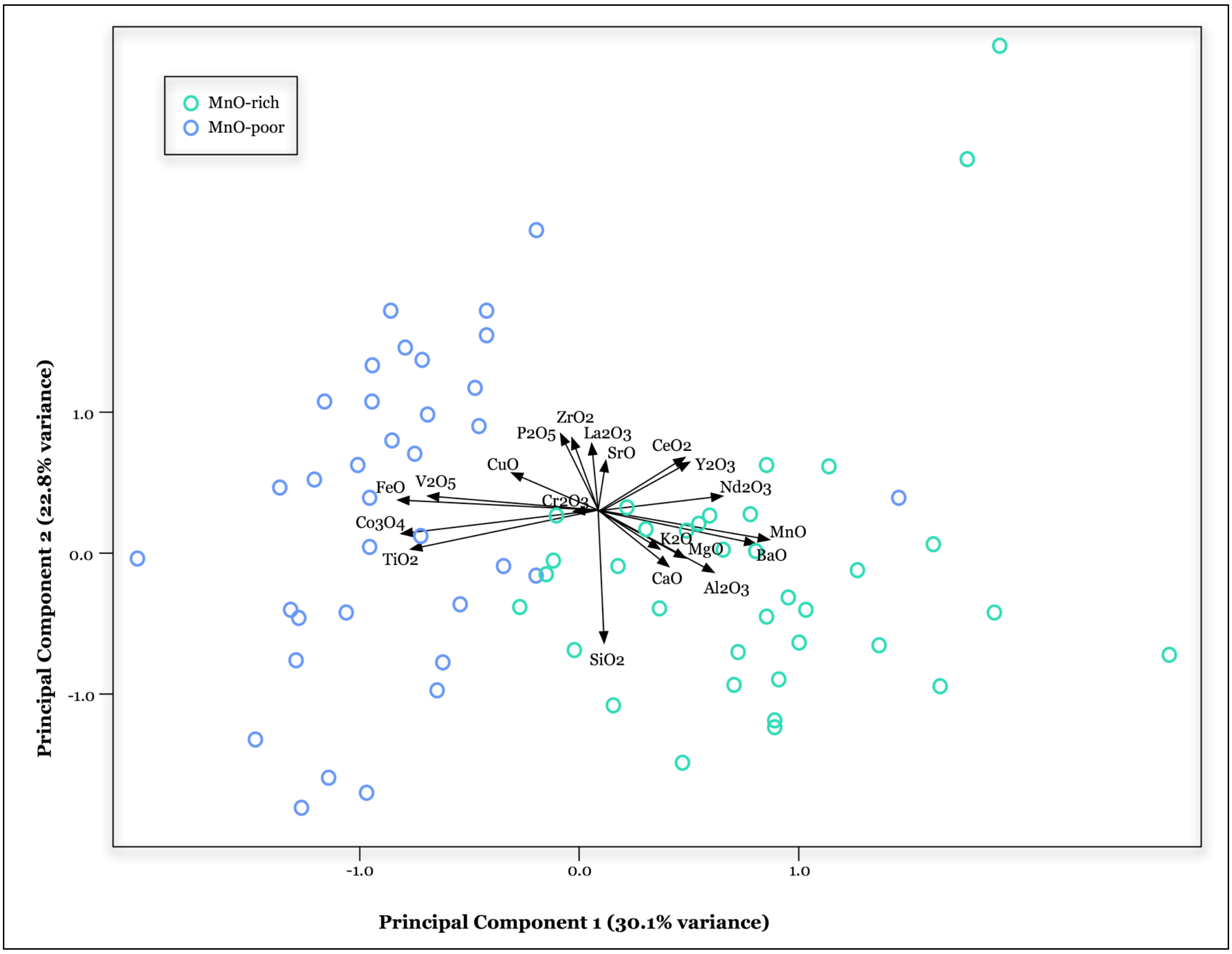


Figure 7.4 Graph of all slag samples from Mwenge in principal component space (PC1 vs. PC2)

The two sets of samples – MnO-rich and MnO-poor – were clearly separated along PC1 (Figure 7.4), with one significant outlier. This was the sample from Furnace Slag 1 from Rugombe. Although broadly similar to the other slag blocks from Rugombe, which showed a considerable amount of variation compared to other sites, this slag block (which derived from the upper fill of the furnace) was significantly enriched with manganese (almost 7wt%) and barium (almost 2wt%) oxides and was the only sample from that site not to contain cobalt oxide. The third component seen to correspond strongly with manganese oxide (neodymium oxide), was present in a relatively high quantity in this sample, although this was not an altogether unusual reading for this site, where neodymium oxide ranged between 300 and 1200ppm. This sample does however appear to be anomalous for this site, and may be indicative of the movement of slag blocks across the landscape.

The apparent absence of titania and cobalt oxides from the samples with high manganese oxide may well be a further indication of the addition of a second ore in these smelts. Neither TiO_2 nor V_2O_5 can be reduced within a bloomery iron smelting furnace, so "both will transfer quantitatively to the slag during smelting" (Miller *et al.* 2001: 406). Co_3O_4 *can* be reduced during smelting, and cobalt's 'siderophilic' nature means it will partition, if only partly, to the iron (Desaulty *et al.* 2009). If present in the iron ores used in all sites, the dilution factor of adding a second manganese ore at certain sites could render those compounds presumably coming mainly with the iron ore – TiO_2, V_2O_5, Co_3O_4 – below the detection limits of the PED-XRF (or considerably lowered) in those instances. This factor might account for the variability in presence or "absence" of titania and vanadium oxide in the slag samples from, for example, Kirongo (*cf.* Table 6.1).

Nevertheless, if this is taken to prove the use of two ores in the Mn-rich samples, it is also relevant to consider whether a similar system was in use at the remaining Mn-poor sites, but with a much lower ratio of manganese-enriched ore to iron ore. To explore both the original hypothesis and this new question, the MnO-rich and MnO-poor sample sub-sets were also analysed separately using principal component analysis (Tables 7.6 and 7.7). Several points of interest were identified.

	MgO	CaO	SrO	SiO_2	Al_2O_3	P_2O_5	K_2O	Cr_2O_3	MnO	BaO	Nd_2O_3	La_2O_3	FeO	CuO	Y_2O_3	ZrO_2	CeO_2	
MgO		0.7	0.6	0.6	0.0	0.2	0.4	-0.1	0.2	0.0	0.2	0.4	-0.6	0.0	-0.2	-0.3	-0.1	MgO
CaO	0.7		0.5	0.7	0.1	-0.1	0.1	-0.4	0.1	0.2	0.1	0.0	-0.7	-0.1	0.0	-0.1	0.2	CaO
SrO	0.6	0.5		0.3	-0.1	0.5	0.2	-0.4	0.2	-0.2	0.0	0.3	-0.4	0.3	0.3	0.2	0.1	SrO
SiO_2	0.6	0.7	0.3		0.1	-0.4	0.0	-0.4	0.2	0.2	0.2	0.2	-0.8	-0.2	-0.2	-0.3	-0.2	SiO_2
Al_2O_3	0.0	0.1	-0.1	0.1		-0.1	-0.3	0.3	0.5	0.5	0.2	-0.3	-0.5	-0.2	0.2	-0.2	0.1	Al_2O_3
P_2O_5	0.2	-0.1	0.5	-0.4	-0.1		0.5	-0.2	-0.1	-0.4	-0.2	0.3	0.2	0.2	0.4	0.5	0.2	P_2O_5
K_2O	0.4	0.1	0.2	0.0	-0.3	0.5		-0.2	-0.4	-0.4	-0.1	0.3	0.0	0.0	-0.2	0.0	0.0	K_2O
Cr_2O_3	-0.1	-0.4	-0.4	-0.4	0.3	-0.2	-0.2		0.0	0.2	0.0	-0.1	0.2	-0.1	-0.3	-0.3	-0.1	Cr_2O_3
MnO	0.2	0.1	0.2	0.2	0.5	-0.1	-0.4	0.0		0.6	0.6	0.3	-0.6	-0.1	0.3	-0.2	0.2	MnO
BaO	0.0	0.2	-0.2	0.2	0.5	-0.4	-0.4	0.2	0.6		0.8	0.2	-0.5	-0.3	0.1	-0.3	0.4	BaO
Nd_2O_3	0.2	0.1	0.0	0.2	0.2	-0.2	-0.1	0.0	0.6	0.8		0.6	-0.5	-0.2	0.2	-0.3	0.5	Nd_2O_3
La_2O_3	0.4	0.0	0.3	0.2	-0.3	0.3	0.3	-0.1	0.3	0.2	0.6		-0.3	0.0	0.2	0.0	0.3	La_2O_3
FeO	-0.6	-0.7	-0.4	-0.8	-0.5	0.2	0.0	0.2	-0.6	-0.5	-0.5	-0.3		0.3	-0.1	0.3	-0.1	FeO
CuO	0.0	-0.1	0.3	-0.2	-0.2	0.2	0.0	-0.1	-0.1	-0.3	-0.2	0.0	0.3		0.1	0.2	0.0	CuO
Y_2O_3	-0.2	0.0	0.3	-0.2	0.2	0.4	-0.2	-0.3	0.3	0.1	0.2	0.2	-0.1	0.1		0.6	0.5	Y_2O_3
ZrO_2	-0.3	-0.1	0.2	-0.3	-0.2	0.5	0.0	-0.3	-0.2	-0.3	-0.3	0.0	0.3	0.2	0.6		0.2	ZrO_2
CeO_2	-0.1	0.2	0.1	-0.2	0.1	0.2	0.0	-0.1	0.2	0.4	0.5	0.3	-0.1	0.0	0.5	0.2		CeO_2

Table 7.6 Correlation matrix for all MnO-rich slag samples from Mwenge

	MgO	Al_2O3	K_2O	CaO	SiO_2	MnO	BaO	FeO	TiO_2	Cr_2O_3	V_2O_5	Co_3O_4	CuO	SrO	ZrO_2	P_2O_5	La_2O_3	CeO_2	Nd_2O_3	
MgO		0.7	0.8	0.7	0.5	-0.1	0.3	-0.7	0.1	0.2	-0.2	-0.1	-0.3	0.0	-0.2	0.0	-0.4	-0.1	-0.2	MgO
Al_2O_3	0.7		0.8	0.6	0.5	0.0	0.3	-0.8	0.3	0.2	-0.2	0.0	-0.1	0.1	-0.2	0.0	-0.4	0.1	-0.2	Al_2O_3
K_2O	0.8	0.8		0.6	0.4	0.0	0.4	-0.7	0.2	0.4	-0.1	0.0	0.0	0.0	-0.1	0.1	-0.4	0.0	-0.2	K_2O
CaO	0.7	0.6	0.6		0.5	-0.4	-0.1	-0.6	0.4	0.3	0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	-0.1	-0.1	CaO
SiO_2	0.5	0.5	0.4	0.5		-0.2	-0.1	-0.9	0.1	-0.3	-0.5	-0.2	-0.6	-0.4	-0.6	-0.5	-0.6	-0.4	-0.5	SiO_2
MnO	-0.1	0.0	0.0	-0.4	-0.2		0.8	0.0	-0.7	-0.4	-0.5	-0.7	-0.1	0.1	0.1	-0.2	-0.1	0.2	0.4	MnO
BaO	0.3	0.3	0.4	-0.1	-0.1	0.8		-0.2	-0.6	-0.1	-0.4	-0.5	-0.1	0.4	0.1	0.0	-0.1	0.4	0.4	BaO
FeO	-0.7	-0.8	-0.7	-0.6	-0.9	0.0	-0.2		-0.1	0.1	0.5	0.3	0.5	0.1	0.4	0.3	0.5	0.2	0.3	FeO
TiO_2	0.1	0.3	0.2	0.4	0.1	-0.7	-0.6	-0.1		0.4	0.6	0.6	0.2	-0.1	0.4	0.4	0.3	0.0	-0.1	TiO_2
Cr_2O_3	0.2	0.2	0.4	0.3	-0.3	-0.4	-0.1	0.1	0.4		0.7	0.7	0.5	0.1	0.2	0.4	0.1	0.1	0.0	Cr_2O_3
V_2O_5	-0.2	-0.2	-0.1	0.1	-0.5	-0.5	-0.4	0.5	0.6	0.7		0.6	0.5	0.2	0.6	0.6	0.5	0.3	0.2	V_2O_5
Co_3O_4	-0.1	0.0	0.0	0.1	-0.2	-0.7	-0.5	0.3	0.6	0.7	0.6		0.6	0.0	0.1	0.3	0.2	0.0	-0.1	Co_3O_4
CuO	-0.3	-0.1	0.0	-0.1	-0.6	-0.1	-0.1	0.5	0.2	0.5	0.5	0.6		0.2	0.4	0.5	0.3	0.3	0.3	CuO
SrO	0.0	0.1	0.0	0.1	-0.4	0.1	0.4	0.1	-0.1	0.1	0.2	0.0	0.2		0.5	0.7	0.7	0.9	0.8	SrO
ZrO_2	-0.2	-0.2	-0.1	-0.1	-0.6	0.1	0.1	0.4	0.4	0.2	0.6	0.1	0.4	0.5		0.7	0.8	0.7	0.7	ZrO_2
P_2O_5	0.0	0.0	0.1	0.1	-0.5	-0.2	0.0	0.3	0.4	0.4	0.6	0.3	0.5	0.7	0.7		0.7	0.7	0.6	P_2O_5
La_2O_3	-0.4	-0.4	-0.4	-0.1	-0.6	-0.1	-0.1	0.5	0.3	0.1	0.5	0.2	0.3	0.7	0.8	0.7		0.7	0.8	La_2O_3
CeO_2	-0.1	0.1	0.0	-0.1	-0.4	0.2	0.4	0.2	0.0	0.1	0.3	0.0	0.3	0.9	0.7	0.7	0.7		0.9	CeO_2
Nd_2O_3	-0.2	-0.2	-0.2	-0.1	-0.5	0.4	0.4	0.3	-0.1	0.0	0.2	-0.1	0.3	0.8	0.7	0.6	0.8	0.9		Nd_2O_3

Table 7.7 Correlation matrix for all MnO-poor slag samples from Mwenge

At first glance, the very strong correlations in the MnO-poor slag samples suggest that fewer materials are contributing to these smelts. Contributions from technical ceramics, fuel ash and ore(s) seem distinct and clear. Correlations in the MnO-rich slags are much weaker, reflecting more variable dilution effects from the larger number of contributing components.

In particular, in the Mn-poor samples, there is a very strong correlation – 0.8 – between manganese and barium oxides, but this diminishes to 0.6 in the Mn-rich samples. This may indicate that a second source of manganese oxide was entering the system in the Mn-rich samples, these two sources most likely comprising the manganese 'flux' *and* the iron ore. This is backed up by the continuing presence of manganese oxide in all samples. As such, manganese oxide can be presumed to be coming with the iron ore anyway, in small amounts, and when manganese oxide also enters the system from a second source, the correlation diminishes. I suggest that this indicates that the MnO-poor smelting systems used only one ore – an iron ore containing a limited extent of associated manganese minerals.

Consequently, manganese oxide continues to be strongly positively correlated with barium oxide in the Mn-poor samples, although not with neodymium and lanthanum in these systems – which may indicate the mineralogy of manganese in the area rather than gangue associations of a Mn-bearing host rock. The strong correspondence between barium and manganese oxides suggests that the mineral root is a hard, black psilomelane. The specific species of this mineral is likely to be the commonly occurring mineral romanèchite ($(Ba,H_2O)_2(Mn^{4+},Mn^{3+})_5O_{10}$) – a "weathering product of manganese-bearing oxides, carbonates and silicates in sedimentary deposits" (http://www.mindat.org/min-3441.html). The ratio of barium to manganese in the Ore B sample from Kisamura (*cf.* Table 7.8; approximately 1:4.5) is close to the ratio of these compounds in the chemically pure form of this mineral (between 1:5 to 2:5, depending on water content).

An examination of the available ore analyses can provide further possibilities as to the nature of the ores used across Mwenge (Table 7.8). As introduced in the earlier chapters, a tantalising suggestion occurs at the later site of Kisamura, where analyses of manganese-rich slag blocks were complemented by the analysis of two possible ore samples excavated from a nearby test pit. Ore A was primarily composed of iron oxide and silica, with significant traces of cobalt and copper oxides. Very little manganese oxide was present in this sample. Conversely, Ore B was primarily composed of alumina and manganese oxide, with some additional silica and iron oxide. Significant trace compounds included nickel, copper and zinc oxides, as well as the rare earth compounds. Barium oxide measured over 4wt%, and the level of neodymium oxide was also very high.

Although hypothetical mass balance scenarios using these two samples were not successful (*cf.* Chapter 6, Part Two), it is suggestive that these two rocks are present at this smelting site, as in combination they match very closely the ore compounds that would be needed to result in the Kisamura slag. Furthermore, the manganese-rich ore (*cf.* Figure 6.54) conforms to the descriptions presented in the ethnographic data. The other sample with a very high manganese oxide content, this time in conjunction with a viable iron oxide content – that from Kirongo – also fits well with ethnographic descriptions of a black and glittery ore (*cf.* Figure 6.17). These ethnographic accounts will be discussed shortly.

	Major and minor compounds												
Mwenge ores	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
Early sites:													
Kyakaturi Ore	/	/	3.18	*2.54*	1.39	0.07	0.07	0.05	0.16	0.04	0.11	0.49	89.98
Rugombe Ore A	0.02	/	2.15	2.10	0.94	0.11	0.01	0.06	0.23	0.09	0.05	0.32	92.55
Rugombe Ore B	0.07	/	0.50	36.60	0.15	0.03	/	0.02	0.07	0.01	0.02	0.46	61.80
Later sites:													
Kirongo Ore	/	0.57	2.56	2.04	/	0.03	0.03	0.01	5.63	/	0.06	11.59	76.32
Kisamura Ore A	0.18	0.01	6.57	34.35	0.61	0.06	0.27	0.04	0.13	0.05	0.52	0.25	56.75
Kisamura Ore B	0.18	/	26.97	18.03	0.55	0.10	0.54	1.62	/	/	0.10	23.16	19.71
Kisamura Ore C	0.33	/	1.13	71.86	/	0.02	0.00	0.02	0.03	0.01	0.01	0.07	26.43
Rukomero F1 Ore	0.11	0.02	3.12	14.60	0.04	0.04	0.05	0.01	0.02	0.01	0.01	0.05	78.27
Rukomero F2 Ore	/	0.03	1.53	11.27	/	0.02	0.04	0.01	0.01	/	0.02	0.04	83.59

	Trace compounds											
Mwenge ores	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	SeO_2 ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm
Early sites:												
Kyakaturi Ore	910	/	84	258	/	127	/	788	456	2348	1090	1044
Rugombe Ore A	960	/	425	60	390	61	/	497	95	487	279	263
Rugombe Ore B	921	/	37	54	/	93	/	211	184	626	409	187
Later sites:												
Kirongo Ore	/	347	/	612		/	/	51	551	/	/	/
Kisamura Ore A	559	/	362	79	/	215	16	141	205	275	250	39
Kisamura Ore B	/	1370	1909	742	/	137	197	214	44216	864	1485	3581
Kisamura Ore C	403	31	151	26	/	/	5	58	/	12	14	27
Rukomero F1 Ore	780	/	/	/	/	/	/	/	/	178	82	/
Rukomero F2 Ore	776	/	/	/	/	/	/	/	/	/	17	/

Table 7.8 Averaged PED-XRF analysis of all excavated ore samples from Mwenge

The other ore samples also seem to correspond (at least to a certain extent) with the compounds seen in the slag blocks from various sites. The particularly high levels of cobalt oxide in the ore samples from Kyakaturi, Rugombe and Rukomero (almost as high as 0.1wt%) go some way to explain the elevated levels of this compound in the slag blocks from these sites (which average at almost 0.05wt%). As mentioned earlier, cobalt, once reduced (as is likely in the environment of a bloomery furnace) will partition to the bloom; for residual cobalt to remain in the slag, either there was a large quantity to start with, or atmospheric conditions inside the furnace were not sufficient to reduce it.

Apart from the manganese-rich ore from Kisamura, levels of alumina and lime remain relatively low in all of these samples. Kirongo is the only ore to show considerable titania content. Trace compounds of nickel, copper, zinc and zirconium oxides also occur in many of these samples.

Statistically, this remains a relatively small sample size per site, and the samples cover an area that presumably encompasses differences in geological background that might diminish any chemical patterns when all the sites are considered together. However, I believe that it is possible to strongly suggest that two separate minerals – one manganese-rich, one iron-rich – are being smelted together at Kirongo, Kisamura and Mirongo Group 2. Conclusive evidence might potentially take the form of the discovery of separate storage piles of ready-to-use ores, as seen at Timna (Hauptmann 2007: 250), but this would be an extremely lucky archaeological find in this region.

Unfortunately, considering the limited temporal data for these sites (due to the current inability to directly date individual smelting episodes) it is very difficult to discuss the circumstances surrounding how and why this technical change was implemented at certain sites, and whether it demonstrates a distinct technological innovation that became dominant in the region over time.

Nevertheless, the data could be used to suggest a more careful choice of raw materials, as slag compositions seem to generally shift to becoming more Mn-rich in an area where both MnO-poor and MnO-rich ores are available. The samples from Mirongo Group 2 are not necessarily associated with the relatively early date from the furnace from Mirongo; the two remaining MnO-rich sites are both dated to the later period of this study. The one remaining site from the later period – Rukomero – which has MnO-poor slag, is further removed from the central Mwenge region and is situated within a slightly different landscape; access to an MnO-rich ore body may not have been possible in that immediate location (although Rukomero is not situated that far from other Mn-using sites) or not sought. There are many different variables that might explain why some sites utilised only iron ore – economic, social, political – while others utilised an additional manganese-rich ore. Yet, the possibility remains that

MnO-rich ores may have been deliberately selected for their fluxing properties. The distinctive appearance of the black manganese-rich ores and the pronounced effect their inclusion would have had on the smelts makes this a plausible suggestion.

A similar, deliberate addition of a separate manganese-rich material has been archaeologically documented in the late medieval bloomery smelting of Harthorpe Mill in County Durham (Tylecote 1962: 288). In the fifteenth century, local smelters had been using nodular iron ore with a manganese content of less than 1wt%, yet contemporary slag remains contained up to 7wt% manganese oxide. This discrepancy was attributed to the addition of crushed-up, twelfth century slag from nearby Hoppyland. During this earlier period, smelters were instead using a high-manganese bog iron ore, with a manganese oxide content of around 15wt%. By using these old slag blocks as a flux in fifteenth century smelting, local iron producers were improving their yield as well as having a positive effect on the "free-running characteristics" of the slag. A similar reuse of high manganese slag was seen in northwest Cameroon, where Oku smelters told of the tradition of using older slag in their smelts, which were later found to contain over 5wt% manganese oxide (Fowler 1990: 68).

Does this represent the male and female ores documented ethnographically:

Several accounts mention the use of 'male' and 'female' ores in more recent iron smelting in western and central Uganda (Roscoe 1923 in Bunyoro, and 1911 in Buganda; Cline 1937), but there appear to be a number of contradictions in terms of descriptions of these two ores, which makes it more difficult to interpret what minerals they might be referring to.

Cline (1937) draws upon Roscoe's early twentieth century observations of Nyoro smelting to surmise that:

> "Ore is either "male" or "female": the first hard, black, and from the surface of the ground; the second soft, red, and mined in tunnels: and a mixture of these "sexes" is necessary for successful smelting. This, however, may be a purely practical consideration, or one with only a slight tinge of ritual; since the hard magnetite requires roasting, which might be accomplished in the smelting furnace if a more tractable ore is mixed with it".
>
> (Cline 1937: 117, drawing upon Roscoe 1923)

Cline's interpretation is that the 'male' ore constitutes a (presumably) colluvial or alluvial magnetite, which is an understandable assumption, but importantly one that was made with no first-hand knowledge of the area. Roscoe's original description of the ores is thus:

> "They [the smelters] had to be able to distinguish between good and bad stone [ore]. There were two kinds of stone in use and in common parlance they were referred to as the male and the female. The male was regarded as better in quality, but it had the disadvantage of being hard to break and prepare for smelting. It was black in colour and was found in the hill Nyaituma, usually on the surface of the ground. The female, or soft, iron was found in Galimuzika Busanga; it was red and lay in layers running into the hillside."
>
> (Roscoe 1923: 217-218)

This account is likely to refer to smelting practices to the north of the Mwenge region, towards the location of the current Bunyoro kingdom (Hoima/Masindi). The hill called Nyaituma that is mentioned (in association with hard/black ore) is in Hoima district (and interestingly is considered a viable modern source of haematite iron ore by the Uganda Government's Department of Geological Survey and Mines). Galimuzika Busanga (marked on the Department of Lands and Surveys 1:50000 Map Sheet 38/4 at grid reference 305797) is also in Hoima district, within the sub-county of Kyabigambire (a place named Galimuzika is also present in Mwenge, although I haven't been able to find a translation for this word).

Describing the mining of the ore (presumably meaning the red ore), he adds:

> "When mining the [unspecified] stone, they did not dig downwards but generally horizontally into the hill-side, following a seam of stone from the point where it was exposed, and when the mine extended some distance into the hill several men might be engaged in the tunnel."
>
> (Roscoe 1923: 219)

Accounts also exist from informants much closer to the research area. In 1994 and 1995, Terry Childs (1998a, 1998b, 1999, 2000), conducted ethnoarchaeological interviews in Mwenge (with an informant (a smith) called Masanairi Ndunga from Nkinga (Sheet 57/3, close to grid ref. 219665), approximately 3km to the south-south-west of Mirongo, and 3km to the east of Rukomero, *cf.* Figure 7.5), and also found reference to the use of two ores: one black and glittery called *obutale*; one red and dense called *entabo* (Childs 1998a: 130), elsewhere described as "a red, clay-like material" (1998b: 114; also Davis 1952: 133). The *entabo* was combined with the *obutale* as they dried before the smelt, giving them the opportunity to 'befriend' or 'embrace'; although genders were not explicitly attributed to them in Childs' accounts, through this use of terminology it is implied.

> "The discovery of a new hill of ore (obutale), a matter of luck, was not a frequent event… Ore was not easily found on Toro hillsides covered with forest, tall grasses, grazing cows and wild animals, so men cooperated in parties of six or more. The teams looked for specific clues to find ore" – significant changes in vegetation or presence of a certain type of beetle that sometimes "dug up glittery black stones that might be ore… If the stones broke easily, they were not ore. If they were hard and emitted sparks when hammered" they were.
>
> (Childs 1998a: 127-128)

> They dug "and got the ore [*obutale*] that looked like what they had seen earlier on the surface. They tasted the stones. They were bitterish [not sweet, not sour]"
>
> (Childs 2000: 204)

According to Childs' informant, mining for *obutale* was hard, dangerous work – heavily ritualised and socially controlled – and it involved digging deep shafts approximately 1m in diameter and 5-8m deep. Collecting *entabo* followed a different procedure:

> "There was no known ritual associated with the discovery of entabo, but it was valuable. Iron-workers paid to obtain it from those who mined it from only a few sources."
>
> (Childs 1998a: 130-131)

And in a different publication of the same year:

> "…entabo seems to have been procured mostly by trade since it was more difficult to find in the region. Research to date indicates that no ritual was associated with the discovery of entabo."
>
> (Childs 1998b: 114)

The implication in Childs' work is that *obutale* is the black and glittery 'male' ore, whereas the *entabo* is the red and soft 'female' ore. However, the descriptions of the materials and the ways that they were collected would be more consistent with Roscoe's account if they were the other way around (assuming of course that they describe the same technology): *entabo* as hard and black, and collected from the surface in localised areas; *obutale* as red and soft, and mined in deep tunnels commonly across the region. Roscoe's suggestion also corresponds more closely both with my experiences in the field – the word *obutale* was used regularly by informants to refer to the iron ore dug from the deep *enambo* pits – as well as with Peter Robertshaw's earlier 1991 fieldwork (of which Terry Childs was a part)[3].

In Robertshaw's unpublished fieldwork notes, he describes *entabo* as a "mixer" material, and he interprets it (upon seeing it at Kisinga hill, more of which below) as a colluvial deposit that had derived from an outcrop at the top of a nearby hill (Robertshaw 1991b).

Further notes from this 1991 field season add more to our knowledge of Mwenge ore procurement within living memory. One informant, Damazo Mayonbo, who at the time was 78 years of age and who was from Buhisi, Ruhoko parish (within only a few kilometres of the site of Kirongo), told of iron ore mining sites at Rugombe, Isandara and Kisinga (at Ruhoko Parish HQ), where mine shafts could be up to 25ft (c. 8m) deep. Other informants mentioned Mukihora and Butiti. Isandara and Kisinga are very close to the site of Kirongo; Rugombe is already known to us. Ore was discovered by initially digging trial pits, and smelters (often from Murongo in Kihura sub-county, approximately 20km to the east of Kisinga, along the main road to Matiri) came and bought the ore at Kisinga. The ore was said to be very pure, and three baskets were enough for a smelt.

Damazo (with Ndunga) later took the researchers to Kigugu (approximately 1.5km to the east of Kirongo, *cf.* Figure 7.5), where the "mixer" (*entabo*) was mined. This mineral is recorded as occurring in gravel and stones in the road, and the stones in which it is found are known as *enyenga*, which (along with *ebyenga* and *ebisengere*) is

[3] -*tare* is the general root for iron ore in the region (Butare, Matale etc.). In Buganda, it refers only to ore from outcrops on upper hillslopes (A. Reid pers. comm. 2010).

Lunyoro for 'slag' (Davis 1952). Robertshaw (again, from unpublished fieldwork notes of the same year) describes this material as a colluvial deposit, which occurs in large blocks as well as gravels:

> "Another substance, called entabo was mined in Kigugu, near Kisinga hill. This substance was also dried. This substance was poured on the ore during smelting to produce a harder metal. A dark, sand-like substance with some sparkling grains."

Childs' informant's account of the *entabo* at Kigugu seems slightly different:

> "They had to dig it up. It was down. It was like digging clay that they used to make pots. It didn't go as deep as the ore … It's those people of long ago that discovered the use of entabo … Entabo looked like it glittered. The potters, after molding, they use some kind of earth to make the pots beautiful. It is reddish earth. Entabo was only used in smelting."
>
> (Childs 2000: 210)

As can be seen from these differing accounts, the descriptions of these substances are highly confusing. Nevertheless, presumably, if this 'mixer' ore was collected from the surface rather than mined in deep pits (thereby leaving little physical evidence of the process), the memory of these *entabo*-collecting sites is not going to be as strong; perhaps this is why, even though we travelled through Kigugu during survey, and worked nearby at Kirongo, no local informants led us to this site and this ore: an unfortunate omission, as it would have been very interesting to analyse a material directly described as *entabo*.

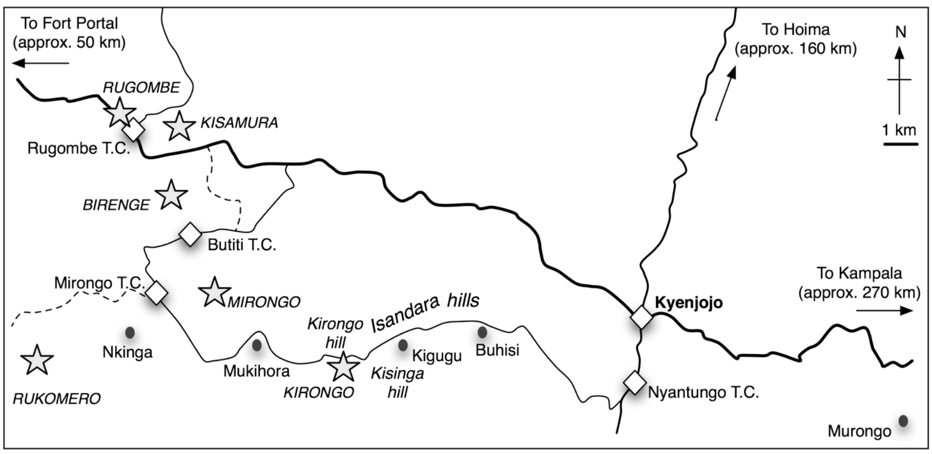


Figure 7.5 Map of central Mwenge showing additional sites mentioned in this chapter. Please refer to Figure 5.1 or 6.1 for legend

To pursue what potential manganese deposits might look like in this region, and to consider if they might match the descriptions in the above accounts, the geology of this region of Uganda was explored further. The region is dominated by Archean basement complex gneisses, with some partly granitised and metamorphosed formations and pockets of intrusive granites, such as the granitic Isandara hills (Figure 7.6; Robertshaw 1991b).

The sedimentary cover sequence in the east of the Mwenge region – the Buganda-Toro system – consists of "argillites (phyllites and schists) with basal quartzites and amphibolites" (Barifaijo 2000: 2). Interestingly, considerable pyrolusite (manganese dioxide) is reported in Kyenjojo, which is "under investigation by a team of geologists from Entebbe, The Geological Survey and Mines Department" (Barifaijo 2000: 216) – such contemporary interest implies a considerable deposit.

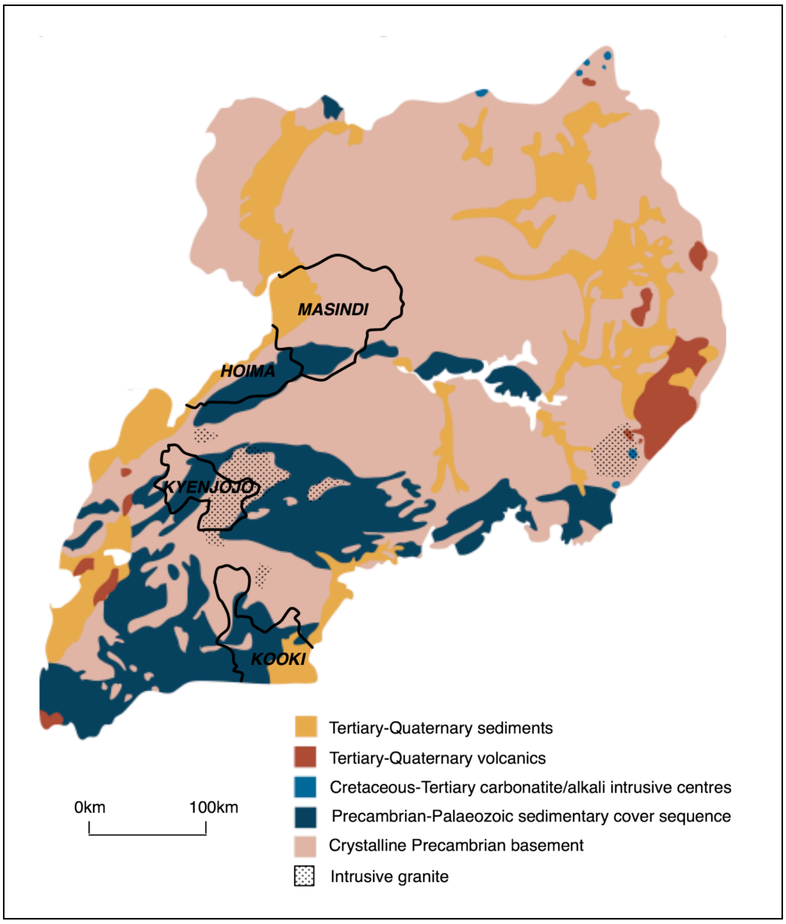


Figure 7.6 Simplified geological map of Uganda, adapted from Barifaijo 2000 and Hinde 2007, and highlighting the counties mentioned in the text

It is possible that one manganese-rich deposit might be a manganiferous laterite, which would be similar in appearance to that shown to Robertshaw in Kisinga. Tropical weathering can leach silica (and other soluble compounds) from parent rocks to form a laterite crust; if the parent rock contains manganese minerals, this will result in a manganiferous laterite. "Manganese laterites are mainly formed on the following types of Precambrian manganese parent rocks, on (1) banded high-temperature manganese oxides, (2) Mn-carbonates (rhodochrosite) and (3) gondites which are highly metamorphic Mg-silicate-bearing rocks with braunite, tephroite, rhodonite, spessartite, (4) rarely, Mn-sulphides with alabandite, hauerite" (Valeton 1994: 114). The granulites of the Precambrian basement complex in this region of Uganda would be consistent with the possible formation of these types of manganiferous laterites over areas rich in pyrolusite; manganese remaining in laterites in the form of pyrolusite has been documented in many areas, for example the lateritic iron ores of Sri Lanka (*cf.* Dissanayake 1980).

The 10 to 30m thick weathering profiles of such laterites tend to comprise – from top to bottom – an upper "manganiferous pebble layer, hard manganiferous crust at the top, soft oxidised layer underlain by a clayey saprolite, and fresh parent rock" (Valeton 1994: 114). Again, this seems consistent with Robertshaw's observations of gravel-like surface deposits. Unfortunately, Robertshaw's fieldwork notes were made available after the fieldwork had been undertaken, and as such, no samples of possible *entabo* sources were sought from Kigugu. However, a sample of lateritic material was collected from nearby Nyantungo sub-county headquarters (Figures 7.7 and 7.8). Upon analysis using PED-XRF, it was found to contain approximately 3wt% MnO against 6wt% FeO (Table 7.9): a high ratio of manganese to iron (especially considering the likely underestimation of MnO by 17%, *cf.* Chapter 4).

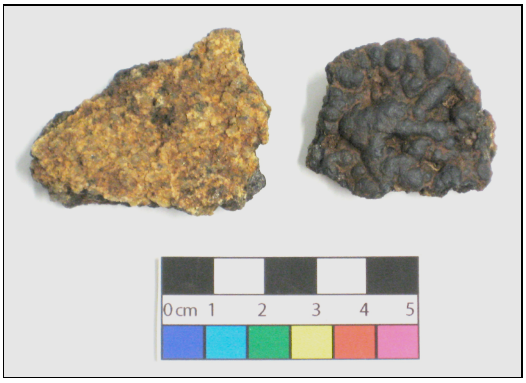


Figure 7.7 Sample of a lateritic deposit collected from Nyantungo sub-county HQ (KYS2)

Figure 7.8 Sample of lateritic deposit crushed prior to milling. Yellowish-white sandy components were manually separated from black sub-metallic components and analysed separately

	Major and minor compounds												
KYS2	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO
Lateritic deposit	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
Sample A	0.41	0.11	14.08	72.22	0.01	/	3.67	0.24	/	/	0.02	2.76	5.86
Sample B	0.39	0.09	14.11	75.44	/	0.01	5.01	0.17	0.05	/	0.01	0.93	3.64

	Trace compounds										
KYS2	Co_3O_4	NiO	CuO	ZnO	Rb_2O	ZrO_2	BaO	La_2O_3	CeO_2	PbO	Analytical
Lateritic deposit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Sample A	1000	77	107	134	207	309	4000	147	1100	458	97.80
Sample B	401	38	38	65	316	296	1084	88	353	209	98.20

Table 7.9 Normalised PED-XRF analysis of the lateritic sample shown in Figures 7.7 and 7.8. Sample A is the black sub-metallic component; Sample B is the yellow sandy component

Of additional note is the broad macroscopic similarity that the Ore B sample from Kisamura (Figure 6.54) bears to an example of a banded high-temperature manganese oxide (Figure 7.9). Romanèchite – the barium-manganese mineral mentioned earlier in this section, and which is often found in association with haematite and pyrolusite – is greyish black and sub-metallic (Figure 7.10), with a hardness of between 5 and 6 Mohs, again consistent with descriptions in the ethnographic literature. This might also be a possible source of the manganese content of the slag blocks in Mwenge.

Figure 7.9 Banded high-temperature manganese oxide, with silica. From Las Bolas, Mexico

Figure 7.10 Romanèchite from Baryte mine, Hesse, Germany. Specimen size approx. 120cm^3

[Figures 7.9 and 7.10 sourced from http://www.mindat.org/gallery.php?min=3441]

One final account exists of the collection and use of iron ores in Mwenge. This derives from an informant in his 70s called E. G. Winyi, of the Basita clan, who was from Rwengoma village, a few kilometres to the west of Fort Portal. In an interview in April 1969, he gave a detailed account of what Buchanan refers to as 'the Mwenge pattern of iron production', that he witnessed whilst visiting his uncle near Kalyamuguru Hill (Mwenge) in 1914. Unfortunately, the place name 'Kalyamuguru' cannot be located on maps 56/4, 57/1 or 57/3.

> "First of all they surveyed a hill which was near water. They say that iron ore needs water... There are two classes of metal which they get from the iron ore: enyondo (this ore produces very tough metal) and ekibale (this ore is used for axes and spears, but it is not as tough). Enyondo is a black, very heavy metal. It is used to make hammers to hammer other types of metals. Hoes were made from a mixture of the two metals… Then they would call a large group of other smiths together to mine the ore… They used a metal pick for digging the iron ore – a piece of enyondo metal fixed in a wooden handle. There might be

> as many as three people in the pit, which was not very deep. They used baskets made of papyrus fixed on ropes to get the ore from the pits…
> The iron stones from the pits were shared among the Basita [clan]… As the stones were extracted, they were smelted… The purified ore is very heavy and is taken and divided among the smiths, who take it away to make the finished tools elsewhere".
>
> (Buchanan 1974a: 103)

This account seems to have several confusing strands. The first is the use of the words *enyondo* and *ekibale*, which at different times are used to refer to both ores and metals. The direct translation of e*nyondo* is in fact 'hammer', the item Winyi purports it makes; *ekibale* has several recorded translations – 'enlarged spleen', 'spirit shrine', 'broken pottery' and 'rock salt' (Davis 1952), none of which seem relevant here. Childs also records the use of *enyondo*[4] as the name of the 'female' hammers used by smiths in Toro (Mwenge). A smith would own a male and a female hammer, different from each other in form and material, and several 'child' hammers (Childs 1998b: 115).

Certain points of Winyi's account are worth noting. *Enyondo* (ore and/or metal) is described as tough, black and heavy, perhaps similar to the 'male' ores that have been encountered previously. Furthermore, Winyi states "hoes were made from a mixture of the two metals". It is unlikely that this would be referring to the mixing of two molten types of iron, or even the welding of two metals (even though welding is a common smithing technique, both 'traditional' hoes, curated within families (*cf.* Figures 7.11 and 7.12), and modern hoes, are constructed from a single piece of iron).

[4] *–nyondo* is the common root for 'hammer' throughout the Great Lakes (A. Reid pers. comm. 2010).

Figure 7.11 Traditional hoe brought to show to us by a visitor (Figure 7.12) to our excavations in Mirongo that had been curated within his family

Figure 7.12 A local visitor to our excavations at Mirongo, shown holding the hoe blade that he brought to show us, as seen in Figure 7.11

What seems more plausible is that this is a further indication of the mixing of two types of ore, recalled by an elderly informant who witnessed (rather than took part in) smelting in his youth. What is particularly interesting – if this account is read as such – is that it suggests that the choice of ore(s) was dependent on the intended use of the produced metal, rather than yield – the frame of reference I had been primarily focusing on in earlier discussions of the advantages of manganese in iron smelting[5]. This echoes the information provided by Robertshaw's informant, Ndunga, who also explained that the addition of *entabo* produced a hardening effect on the resulting metal. Nevertheless, it is relevant to note that the different accounts of ore procurement do not exactly correspond in all aspects.

It has not been possible to definitively pinpoint what minerals the *entabo* and *obutale* comprised, as the ethnographic accounts are somewhat inconsistent (*cf.* Table 7.10). How should these differences be accounted for? Do they result from the waning memories of the elderly informants? Or do we need to confront the expectation that these accounts *should* be consistent. Each account only describes a smelting approach practiced by a discrete group of smelters. However, these don't appear to be secret materials, hidden from practitioners. If accounts are to be believed, *entabo* was available for purchase in local markets – if this is the case, it is intriguing that different accounts exist as to its nature.

	Location	Informant	Ore A	Ore B
Roscoe (1923)	Hoima	Not given	Male, black, hard to break, found on surface	Female, red, soft, layers running into hillside, mined
Buchanan (1974)	Mwenge	E. G. Winyi	*Enyondo*, produces a tough metal, black, heavy	*Ekibale*, not as tough
Robertshaw (1991)	Mwenge	Damazo Mayonbo and Masanairi Ndunga	No description, mined from *enambo*, very pure. Discovered by following the *kahinda* beetle	A 'mixer', *entabo*, mined in Kigugu, produces a harder metal, dark, sand-like gravel, some sparkling grains, colluvial deposit
Childs (1998a, 1998b, 1999, 2000)	Mwenge	Masanairi Ndunga	Black and glittery, *obutale*, mined (with rituals) from hillside	Red and dense, *entabo*, glittery, no rituals, traded

Table 7.10 Summary table, presenting varying accounts of ore use in western Uganda

Moving away from Mwenge, there are other nearby regions where 'male' and 'female' ores were said to have been used. Cline (1937: 47-48), again referring to an account

[5] and indicative perhaps of some common underlying economic assumptions and expectations of Western researchers.

by Roscoe (1911: 379), but this time regarding Baganda smelters of the Bushbuck clan on the border of Kooki and western Buddu[6], reiterates the use of a hard 'male' ore and the soft 'female' ore in this region of Uganda too, and suggested once more that this referred to a magnetite 'male' ore and a haematite 'female' ore. MacLean's informant in the same region again noted the use of two ores, and although her informant could not be more specific about their nature, MacLean recorded the occurrence of yellowish-brown limonite and black goethite across the landscape (MacLean 1996: 29).

This is very close to the region where the site of Kiwesi is situated (a site which will be reported in detail elsewhere, but for the purposes of comparison see Appendix A). From a metallurgical perspective, there were not high levels of manganese oxide present in this slag, and from an archaeological perspective, of the very many fragments of ore that were excavated from the furnace pit all seemed the same material. The people who live in Kiwesi today associate themselves with Bunyoro, and believe that their predecessors came from there – a point that is very interesting when considering the dynamics of the later kingdom histories of the area (which will be discussed in the next chapter). Furthermore, the furnace that was excavated at Kiwesi did not conform to the description of a furnace offered by Roscoe as 'typical' for that region (again to be discussed later). It seems likely therefore that Roscoe is describing a specific approach to smelting that does not encompass the range of possible variables that were being implemented in the region.

Cline (1937: 46) mentions one final example of smelters who utilised genderised ores. These were the Jur (a Luo group), of southern Sudan:

> "The iron ore, which is broken into small pieces measuring about one inch cube, is separable into two distinct kinds, known to the Jur native as the male and female elements 'Obau' and 'Okina', and it is the general belief that both of these substances must be present before iron can be produced."
>
> (Crawhall 1933: 41)

[6] A. Reid (pers. comm. 2010) suggests Mpigi as a rough location for the smelting that Roscoe documented in Buganda.

Again, the nature of these two materials is not specified. Other similar examples have been noted more recently from Cameroon. Babungo smelters used limonite and haematite ores of different colours, again classified as male and female, their combination necessary for successful iron production (Fowler 1990: 203). Rowlands and Warnier also described the mixing of a male and a female 'ore' in We/Isu smelting (1993: 524): one (the male) a ferrous gravel, the other, a clay. Closer to Uganda, Marakwet and Atharaka smelters (of western Kenya) are also reported as referring to different ores as male and female or husband and wife (Brown 1995: 45), and Brown also reports that Somali smelters referred to iron ore as female and iron metal as male.

One interesting aside, on the subject of the manganese contents of many of the Mwenge slag blocks, is the contribution it may have made to the colour of the slag. As has been noted in some of the site descriptions, several sites had bluish/green slag. Hauptmann (2007: 196), in a discussion of the use of manganese ores in glass production, mentions the effect of different manganese valences on the colour of Fe-containing glass:

> "Fe^{2+}-containing glass, this is typically blue-green colored (just like the slag glass often found in ancient smithies) becomes yellowish brownish with an increasing Fe^{3+} content; if at the same time the Mn oxide content is high it becomes increasingly yellow-brown."

The blue-green slag was primarily noted at a site that was later found to have the lowest levels of manganese oxide, namely Kyakaturi. It is perhaps possible that the higher manganese oxide levels at the remaining sites inhibited the formation of a blue-green glassy phase, hence answering a question originally posed in the first section of Chapter 5. It may be that colour (among other factors) served as a proxy measure of the 'right quality' when smelters assessed their slag throughout the course of a smelt.

FURTHER FLUXING AGENTS

> "Deliberate utilization of fluxing agents is, in modern metallurgy, essential for the controlling of the smelting processes in order to produce low viscosity, easy flowing slag melts with high reactivities and low temperatures of solidification.

> According to their chemical composition, fluxing agents can be divided into basic (limestone, soda, and iron oxides), acidic (quartz, glass shales) and neutral (fluorite, borax)."
>
> (Hauptmann 2007: 249)

The utilisation in Mwenge of one fluxing agent – manganese oxide – has already been discussed at length in the previous section. This basic flux would have behaved as outlined in the quotation above, encouraging the formation of a fluid slag, with a low solidification temperature as well as reacting with the melt to form a knebelitic slag rather than a fayalitic one. The addition of such a flux can "lower the structural complexity (i.e. breaking Si-O-Si linkages in the network structure), enabling the slag to separate from the metal more easily"; adding lime "increases the activity coefficient of wüstite", also lowering the amount of iron lost to the slag (Todd and Charles 1978: 70).

Although comparatively rare in the recorded archaeometallurgy of sub-Saharan Africa there are several accounts of other fluxes – which Cline (1937: 52) describes as "sophisticated, special developments" – being used in the iron production and working industries across the rest of Africa. As examples, Cline documents the use of ferrosilicate slag by Yoruban smelters in their smelting technology (1937: 31-32), and suggests that Wafipa smelters might have used limestone and bone[7] (1937: 52, 74). Even the selection of highly calcareous trees for charcoal has been suggested as a deliberate fluxing choice (Schmidt 1997: 115). The effect of the relatively calcareous charcoal used in the Mwenge smelts will be discussed in the following section.

Returning to the evidence in western Uganda, at one early site in Mwenge – Kyakaturi – the use of a flux other than a manganiferous one has been suggested (*cf.* Chapter 5). The chemical signature of the slag from Kyakaturi was low in manganese oxide relative to the other sites in the region, averaging less than 1wt%; lime levels approached on average 3wt% and iron oxide was relatively low at approximately 55wt%. The technical ceramics associated with the site were highly refractory, and

[7] Although the technical benefit of adding bone as a flux is debatable in this context, considering the refractory nature (thermally and chemically) of the apatite bone mineral.

the ratios of alumina to silica in the slag samples were lower than those in the technical ceramic samples; the ceramic contribution to the melt is likely to have been relatively limited. Yet, a fragment of unreduced ore excavated from the furnace was found to be very rich in iron oxide (c. 90wt% FeO) with very little silica (<3wt%) and gangue.

Many iron ores are self-fluxing, that is to say they contain enough quartz and clay minerals in addition to iron oxides that contribute to the melt and allow slag to form. If an ore contains no or very little gangue, which seems potentially the case in Kyakaturi, then such minerals have to be added manually to enable the formation of a slag and the reduction of iron. The very rich ore at Kyakaturi would not have been easy to smelt on its own; with such low silica and gangue levels it would be difficult for slag to form – a happenstance needed to protect the forming bloom from re-oxidisation and to provide a medium by which to encourage the melting and removal of unwanted minerals from the iron oxides. As Tylecote (1962: 182) tells us, "the best ore for smelting purposes is not necessarily that with the highest iron content as mined". In order for slag to form with such an ore, replacement 'gangue' material has to enter the melt through contributions from the technical ceramics, directly added fluxes, or to a lesser extent, charcoal ash.

In the case of the Mafa smelting documented by Nic David and others in northern Cameroon, an iron ore composed of 85wt% iron oxides (primarily magnetite, with some oxidised to haematite at a ratio of 4:1) and only 15wt% gangue was smelted (David *et al.* 1989). In order for this to take place, the single tuyère that was used in the smelt made a significant contribution to the melt, providing key fluxing components to this non-self-slagging ore. The clay of this tuyère was specially selected, and it contained high proportions of earth alkali and iron oxides; it was not a highly refractory material. In all, nearly 40cm of tuyère was consumed by the melt, and a very high yield of iron was extracted from the ore. A similar 'sacrifice' of tuyères to the melt is likely to have been the case in the first millennium BC iron smelting of ores with an iron oxide content of between 85 and 95wt% at Tell Hammeh in Jordan (Veldhuijzen 2005; Veldhuijzen and Rehren 2007).

One further intimation of a flux is Childs' informant's account of the process of the smelt:

> "Red earth … is kept ready during the smelting. You'd put it when the ore is about to form so that it's able to stick with the ore as it formed together with the entabo. When the iron starts sparking, he then sprinkles in the earth. They add it to make the entabo and the ore becomes hard …, to be able to stick together…"
>
> (Childs 2000: 223)

This addition of a clayey substance such as this would mimic the consumption of technical ceramic clay into the melt, whilst allowing the tuyères themselves to be made of highly refractory clays and not degrade through the course of the smelt.

An alternative was suggested at Kyakaturi. Due to the highly refractory nature of the technical ceramics at Kyakaturi, it is unlikely that they would have melted into the slag. However, as presented in Chapter 5, a piece of quartzitic rock that was also excavated from the furnace suggested the addition of a crushed quartzitic flux within these smelting systems. The use of quartz as a flux has been previously documented in an African iron smelting technology at Phalaborwa, where quartz-rich sand from nearby river beds was used to supplement a very pure titaniferous magnetite ore (van der Merwe and Killick 1979; Miller *et al.* 2001). Such addition of quartz – an acidic flux – would have provided the necessary silica with which to enable the formation of fayalite – Fe_2SiO_4. With few other contributing compounds, this would create a fayalite-dominated slag; this is indeed the case at Kyakaturi (*cf.* Figures 5.22, 5.23, 5.24).

Cline (1937: 74) also documents the use of quartz as a flux in the smelting of iron in southern Africa by Mumbwa smelters, and posits that this technological feature may well have transferred from copper smelting in the local area, where the use of fluxes was already established. He notes that further utilisation of quartz fluxes in iron smelting might also have occurred in southern Zimbabwe and Zambia. Further north he suggests the use of fluxes only for welding, citing the examples of the Maasai utilising crushed mollusc shells (see also Brown 1995), and the Kiziba (south-western Great Lakes) and Karamojong (north-eastern Uganda) using powdered old tuyères to prevent the re-oxidisation of the iron metal during blacksmithing. Roscoe's account of making an iron hammer in Bunyoro also included the use of what is likely to be a flux. Two billets of iron were heated and "smeared with clay from an ant-hill", heated once more and welded together to construct the item (Roscoe 1923: 224). Termites tend to preferentially sort quartz grains from the soil matrix (*cf.* Hesse 1995), making the 'clay' that Roscoe mentions likely to be very quartz rich, acting therefore as a flux for the welding operation.

What would be most interesting would be to be able to pinpoint the time and circumstances that the "effects of fluxing agents were first recognized and utilized deliberately as a technological innovation" (Hauptmann 2007: 250), in this case both the manganese oxide and silica scenarios, thereby examining changes in technology over time. Unfortunately, without the possibility of accurate and precise dating of individual smelting episodes, and with the current small-scale knowledge of smelting across the region, this line of investigation cannot be much developed at the moment. Hopefully in the future a more thorough picture can be developed of these significant technological nuances, yet it appears in a broad sense that smelters are responding and adapting their technologies to differences in environment, whether geological, social or economic.

TECHNICAL CERAMICS

All of the analysed ceramics from Mwenge were relatively refractory, with high alumina contents (Table 7.11). As discussed in the previous section regarding fluxing agents, in many of the smelting scenarios presented, this means that the technical ceramics would have made a comparatively small contribution to the melts, although more at some sites than others (i.e. Mirongo Group 1, Rugombe, Kirongo and Rukomero). This was inferred through estimations of the melting temperature of the ceramics, estimations of the solidification temperature of the slag samples, ratios of alumina to silica in the slag and ceramic samples, and other compounds likely to have derived from the ceramics, as well as archaeological evidence such as the visible erosion of furnace wall (e.g. Rukomero Furnace 2, *cf.* Figure 6.77).

Tuyères	Major and minor compounds												
	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
KTR Tuyère A	0.27	0.09	18.58	75.23	/	0.05	1.80	0.15	1.05	/	0.01	0.02	2.54
KTR Tuyère B	0.24	0.35	21.42	71.56	/	0.06	1.93	0.24	1.19	0.00	0.01	0.02	2.69
MNG Tuyère A	0.37	0.31	20.68	71.98	0.02	0.04	0.69	0.23	1.44	0.01	0.02	0.02	4.02
MNG Tuyère B	0.23	0.20	18.47	74.56	/	0.03	0.60	0.14	1.47	0.01	0.02	0.03	4.10
RGB Tuyère (016)	0.35	0.40	21.79	70.88	/	0.03	0.64	0.38	1.67	0.01	0.02	0.05	3.59
RGB Tuyère (017)	0.19	0.28	27.82	67.31	0.03	0.05	0.43	0.23	1.40	0.00	0.02	0.01	2.01
KSM Tuyère	0.22	0.19	23.31	70.69	/	0.03	1.86	0.12	1.02	0.01	0.01	0.03	2.39
RKM Tr1 Tuyère B	0.39	0.63	23.12	58.74	1.60	0.08	1.50	1.57	2.60	0.04	0.02	0.08	9.40
RKM Tr1 Tuyère A	0.09	0.61	23.34	60.95	0.75	0.07	1.45	1.44	1.82	0.04	0.02	0.05	9.19

Tuyères	Trace compounds													
	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	Rb_2O ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	Nb_2O_5 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	PbO ppm
KTR Tuyère A	47	29	34	95	77	49	/	714	51	552	114	193	136	/
KTR Tuyère B	54	45	45	61	96	62	/	808	52	866	199	290	226	/
MNG Tuyère A	56	46	121	75	43	35	/	582	/	452	56	85	100	/
MNG Tuyère B	63	42	137	74	31	19	/	577	/	201	116	145	112	/
RGB Tuyère (016)	83	61	52	63	29	43	/	746	/	428	165	250	162	43
RGB Tuyère (017)	48	38	80	37	45	42	/	729	/	579	217	250	214	62
KSM Tuyère	42	29	71	48	80	33	14	498	/	340	60	84	110	/
RKM Tr1 Tuyère B	181	58	112	79	59	147	/	836	/	489	69	73	75	/
RKM Tr1 Tuyère A	126	80	95	115	62	150	/	613	/	560	44	70	68	/

Table 7.11 Averaged compositional values for tuyères from all sites in Mwenge

Roscoe (1923: 226) describes the nature and procurement of local clays for pottery, presumably in what are now the districts of Masindi and Hoima:

> "Two kinds of clay, both found in swamps or marshy land, were in general use, one being white and the other black. The common cooking and water-pots were made from the latter."

It is probable that the white colour of the clay *not* used for cooking pots indicates that it was from a kaolinitic source. Many of the analysed tuyères from Mwenge seem also to have been made from kaolinitic clays, with high alumina contents, higher than that in the clays used to manufacture the domestic pottery. We know that kaolinitic clay was used for the manufacture of tuyères for smelting in other areas of this region of the Great Lakes, including Buganda, Rwanda and northwest Tanzania (Schmidt 1997; Humphris 2004, 2010). The use of technical ceramics manufactured from extremely refractory kaolinitic clays has been documented by Rehren and Papachristou (2003: 402) in the production of crucible steel in Central Asia in the 9th to 12th centuries AD, and in the manufacture of Hessian crucibles in 15th century Germany (Martinón-Torres *et al.* 2006), as these ceramics had to withstand very high temperatures. Similarly, in bloomery smelting operations, especially those where the tuyères extend some way into the furnace, the tuyère tips have to bear the high temperatures and reducing atmospheres of a furnace without structurally deforming: "any melting or bloating which causes the tip to collapse obstructs the flow of … air into the furnace" (Childs 1989: 146). Roscoe describes that the clay for the Nyoro furnace he witnessed being used "baked hard and did not crumble", suggesting this was also a highly refractory clay, especially as this style of furnace comprised a self-supporting clay 'hood' formed above the furnace pit (1923: 220).

Most of the tuyères seemed low-fired, which is likely to indicate that these tuyères were left out to dry rather than being fired prior to a smelt. This is a feasible suggestion drawing upon ethnographic evidence from the wider region (e.g. Fowler 1990; Schmidt 1997; Humphris 2010). Childs' informant recollects that the tuyères measured almost one metre in length (Childs 2000: 218). The addition of grass may have improved the workability of these clays.

A common (and relatively unusual) thread running through all the analyses of the technical ceramics from Mwenge was the use of grog temper. This has both technical and cultural implications – these inclusions are likely to have improved the performance of the items made from these clays, and the consistent repetition of this technology across the research area is culturally interesting as shared knowledge in itself. Indeed, during survey, when enquiring from local residents about the presence or absence of broken old pottery sherds in the area, several mentioned that they might be hard to find because of their reuse in ceramic manufacture. In Mwenge, the temper (*ensibo*) used to construct the bellows was specifically identified as grog, made from the ground up sherds of old, broken cooking pots, with all 'stones' removed from the ceramic fabric: "they would sometimes put in slag but they feared it would burst the bellows and the tuyère in place of making them stronger" (Childs 2000: 212).

Grog appears to be an established and dominant approach to tempering in the region: it is a common technique in the production of domestic pottery in Buganda (Giblin 2003), and it is also discussed in Schmidt's reconstruction of Haya smelting in north-west Tanzania:

> There was discussion about "whether pulverised slag or sherds from old tuyères and pottery should be used as tempering material in the tuyère clay. Both views were argued strongly until it was decided to proceed with slag, a material commonly used to temper clay used for pottery and in forging tuyères, not smelting tuyères… The head smelter insisted he had never before used slag as tempering; rather he had crushed used tuyères (grog)"… Later, the head smelter "concluded that the tuyères would henceforth be tempered with small (2 to 4mm) pieces of broken pot and tuyère."
>
> (Schmidt 1997: 62-63)

The documentation of this discussion is particularly interesting. What is seen is the disagreement between the experiences and memories of the head smelter and the working knowledge of several younger smiths, accustomed to working at a forge, over the choice and tempering of clay for the tuyères of a smelt. The young smiths were adamant on using a highly refractory clay with slag temper; the old smelter would have preferred a different clay (inaccessible at the time of the reconstruction), tempered with grog. As Schmidt states: "the use of a clay adequate for forging tuyères was a decision that would have serious and negative implications for iron smelting" (1997b: 62). What worked well in one iron-working context was not suitable for another; the later, successful smelts utilised grog-tempered tuyères that lost up to 20cm in length to the melt (1997b: 101). Childs' informant also notes that different tuyères were used for smelting and forging, though the difference between these two types is not specified (Childs 2000: 213).

Several benefits exist from the use of crushed pottery as temper, which increases structural stability and minimises cracking, both during drying and high temperature use. As these materials (both the ceramic matrix and the grog inclusions) share similar rates of thermal expansion, the chances of the fabric cracking during exposure to the very high temperatures of the furnace is reduced (Rye 1981; Childs 1989) − a characteristic easily noted by iron workers:

> "The importance of the temper is to strengthen what has been molded, so that it does not burst. If you don't add temper and you put it in the fire, "pop." It bursts."
>
> (Childs 2000: 212)

Voids created by these inclusions can also accommodate expanding gases that might otherwise cause bloating (Childs 1989: 148). Broken pottery and tuyère sherds also require minimal effort to collect and process, making them a cheap and accessible type of temper.

Overall, the continuation of the grog temper throughout the Mwenge region is interesting and relatively unusual, although not for the region; a corresponding heavy quartz temper was also the norm. Furthermore, the kaolinitic nature of the tuyère clays is of note. The bulk chemical analysis of only a few sites seemed to suggest a contribution to the melt of the technical ceramics – these were Rugombe, and probably to a lesser extent, Mirongo Group 1 and Rukomero. Disparity in the frequency of tuyère remains from site to site was also interesting. Several sites in Mwenge – all of them the later sites (Kirongo, Kisamura, Rukomero) – had few or no tuyères present. Is this reflective of a different application of tuyères? A use of fewer tuyères per smelt, the reuse of tuyère fragments as temper in either old or modern pottery technologies, or some other factor? Unfortunately, this is difficult to ascertain.

PLANTS AND FUEL

The final contributing factor to be examined in this section is the nature and role of the plants used in these smelts. Fuel ash can make a significant contribution to the melt, particularly in levels of magnesia, phosphate, sulphur, potash, lime and strontium (Iles and Martinón-Torres 2009; Charlton *et al.* 2010). In several of these Mwenge smelts, it appears that fuel ash may have been inputting significant amounts of lime and phosphate that would have had a tangible effect on the operation and outcomes of the smelts, especially as contributions from technical ceramics seem to be minimal across the sample set. To illustrate this with an example, the ore at Kyakaturi contains a negligible amount of lime yet the slag samples contain on average almost 3wt%. With little or no contribution from the technical ceramics proposed – and with very low levels of lime present in the ceramics anyway – this lime must therefore be entering the smelts from an alternative source.

Although sources of iron ore were widespread across the region, good choices of fuel were not always as easy to find (Schoenbrun 1998: 26). The choice of tree for charcoal is always an important decision for smelters, as different types of wood charcoal have very different qualities when burned. Variables of particular relevance in this context include the bulk density of the charcoal, the rate of burning and intensity of heat generated, as well as the amount of ash produced and the chemical contributions that this ash will make to the smelt. Schmidt (1997: 115) suggests that some smelters in sub-Saharan Africa consciously selected specific tree species based on their fluxing qualities, particularly for their lime contents. In his work in Buhaya, he identifies the lime deriving from the wood charcoal as acting as a 'minor flux', as for every smelt approximately 100kg of charcoal was burned. He posits that the grass packing of the furnace pits would also have contributed towards localised fluxing, feeding an additional 80g of calcium into each melt, which he suggests would impact upon the fluidity of the slag within the pit (Schmidt 1997: 115-116), although the relevance of this to the progression of the smelt is debateable.

To examine the fuel ash inputs in the Mwenge smelts presented here, the correlations of possible fuel ash compounds were investigated per site to ascertain which compounds were associated with the charcoal in each area (see Figures 7.13 to 7.19)[8]. Some correlations were stronger than others, as would be expected.

At Kyakaturi (Figure 7.13), magnesia, lime and strontium oxide are particularly closely matched suggesting that these are the compounds that are coming solely from the fuel ash. Phosphate is not clearly correlated with these compounds; as we know from the PED-XRF results of the possible ore source at this site, phosphate is likely to be primarily entering the system from the ore. The lime in the slag however, is likely to derive primarily from the fuel ash.

[8] Although it is important to take into account that if the smelt is effective, iron oxide will be removed from the system leaving all other compounds enriched in the slag, and resulting in positive correlations among the other contributing components (i.e. gangue, ceramic, ash).

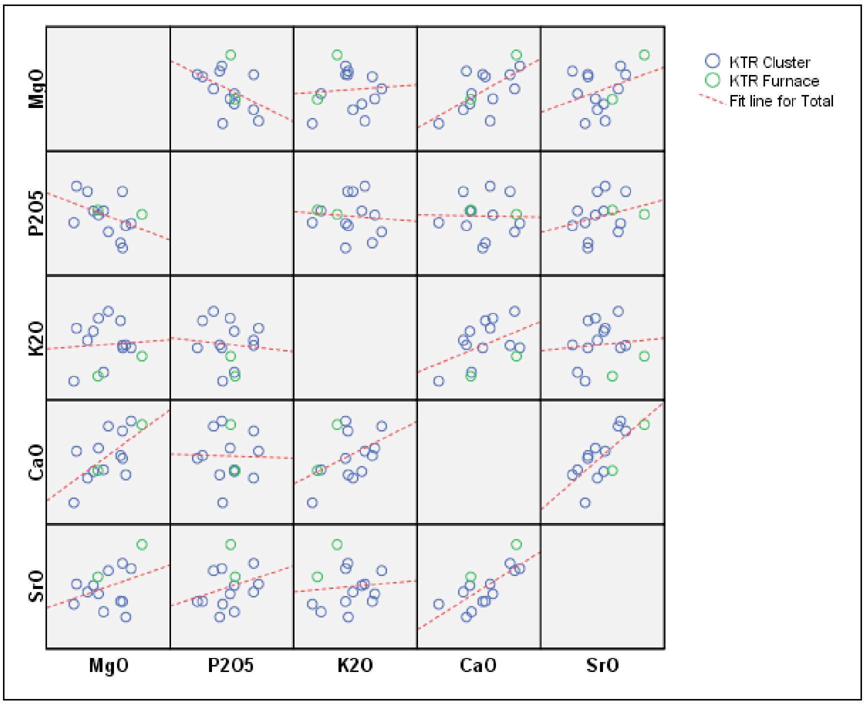


Figure 7.13 Correlations between possible fuel ash compounds in slag blocks from Kyakaturi calculated from the normalised PED-XRF data presented in Table 5.1

The two groups at Mirongo were considered separately (Figure 7.14, and also *cf.* Tables 5.9 and 5.10). The manganese-rich Group 2 showed strong and clear positive correlations among all five of the suggested fuel ash compounds; Group 1 showed slightly weaker correlations, following much more closely the patterns seen in Kyakaturi. This might be due to a greater contribution of technical ceramics in the Group 1 smelts. Magnesia, phosphate, lime and strontium oxide show the strongest links. The correlation with potash is the most reduced, perhaps due to the evaporation of potash at high temperatures, which would thus distort the proportions remaining in the slag. However, the higher lime content of the Group 2 samples suggests that there may be more fuel ash entering the system than in the Group 1 smelts.

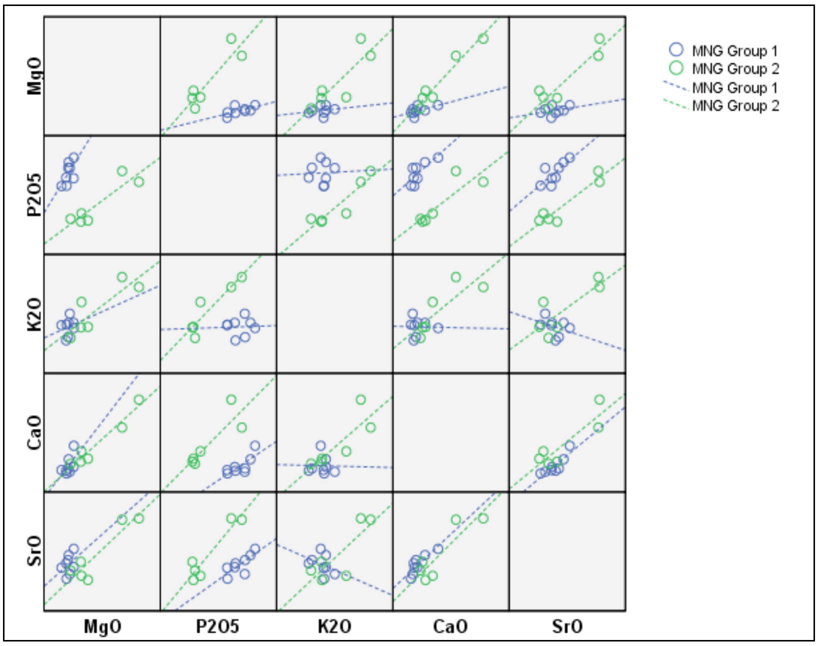


Figure 7.14 Correlations between possible fuel ash compounds in slag blocks from Mirongo calculated from the normalised PED-XRF data presented in Table 5.5

At Rugombe (Figure 7.15), the correlations were also not as clear, with strong correlations between magnesia and potash, and phosphate and strontium oxide respectively in the furnace slag. Lime and potash correlated to some extent in both sets of samples. A greater contribution of technical ceramics may have weakened the correlations that can be identified in these compounds, as seen also in the Mirongo sample set.

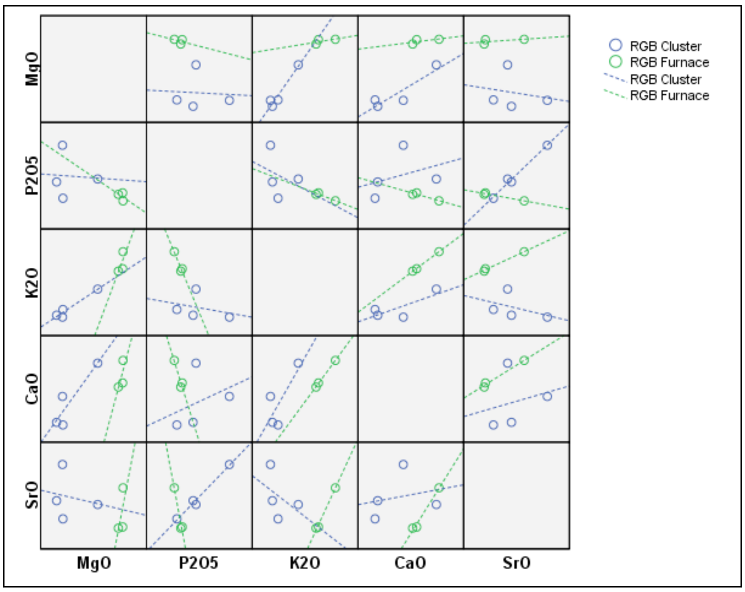


Figure 7.15 Correlations between possible fuel ash compounds in slag blocks from Rugombe calculated from the normalised PED-XRF data presented in Table 5.13

At Kirongo (Figure 7.16) the correlations between lime, potash and magnesia are strong; phosphate and strontium oxide have strong correlations together but not with the remaining compounds. This appears anomalous: neither of these two compounds were present in the possible ore sample that was analysed. In Chapter 6 it had been suggested that the phosphate content of the slag may have been explained either by phosphate coming from the fuel ash or coming in a second ore. The lack of positive correlation between the phosphate and the other fuel ash compounds may indicate a non-fuel ash source for this phosphate. Unfortunately, this proposition is confused by the lack of tuyère samples from this site: it is in principle possible that the strong lime-potash-magnesia correlation is directly associated with the technical ceramic component of the melts (although the lack of calcareous ceramics in the region makes this unlikely). If so, the strong phosphate-strontium oxide correlation would suffice to explain this compound as coming from the fuel ash. This was double checked by looking at the correlations of magnesia, potash and lime with silica and alumina (Figure 7.17). However, although silica correlated well, alumina did not carry as strong a correlation. This may be due to the alumina content of the Kirongo ore.

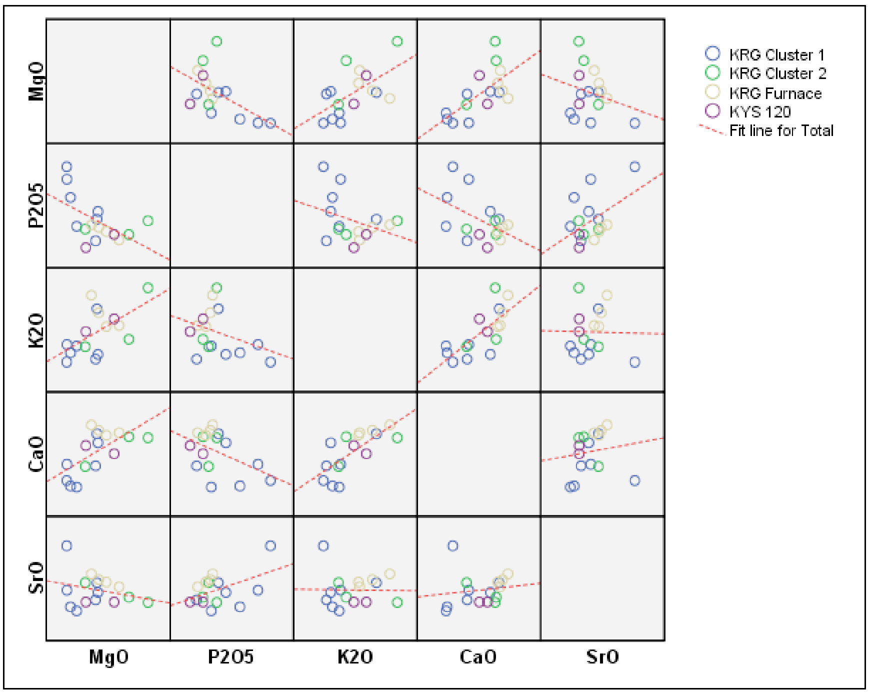


Figure 7.16 Correlations between possible fuel ash compounds in slag blocks from Kirongo calculated from the normalised PED-XRF data presented in Table 6.1

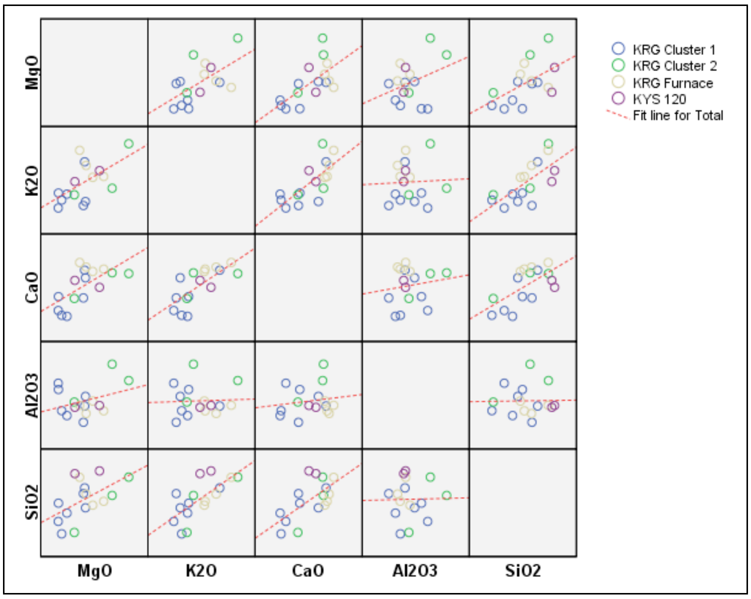


Figure 7.17 Correlations between possible technical ceramic compounds in slag blocks from Kirongo calculated from the normalised PED-XRF data presented in Table 6.1

Kisamura (Figure 7.18) again shows fuel ash compound correlations that are relatively weak. This may be due to the use of more than one ore (as suggested previously), and in fact the possible ore samples analysed (Ores A and B) did contain moderate levels of compounds usually associated with fuel ash, including phosphate, potash, lime and strontium, which may have confused the correlations.

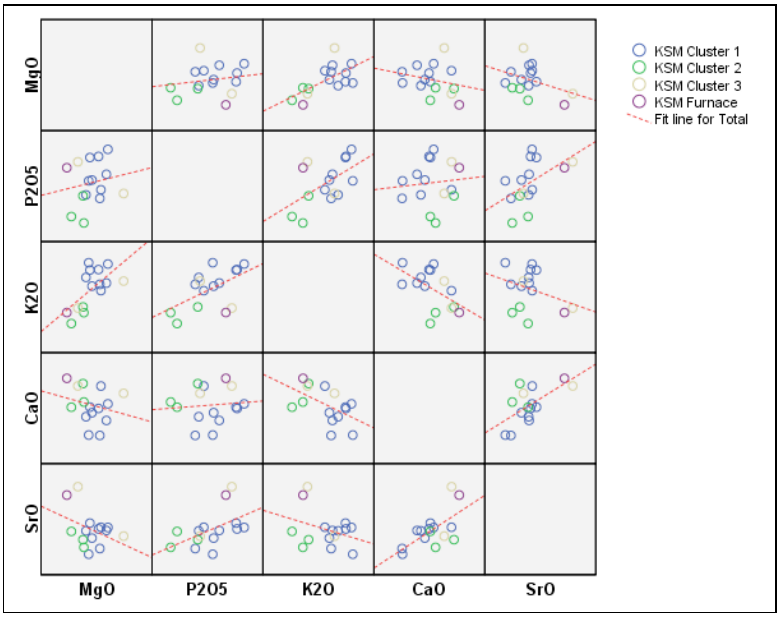


Figure 7.18 Correlations between possible fuel ash compounds in slag blocks from Kisamura calculated from the normalised PED-XRF data presented in Table 6.8

Finally, at Rukomero (Figure 7.19), all possible fuel ash compounds bar phosphate correlate strongly and positively. This would happily account for the only moderate levels of lime in the slag samples from this site (on average approximately 1wt%, the lowest readings of all these sites), and the very low levels of phosphate in these slag blocks. Although it is likely that the fuel ash *is* making a contribution to the final slag composition here, the species of charcoal does not appear to contain significant amounts of phosphate (although at such low levels, analytical certainty for phosphate may be compromised, *cf.* Chapter 4).

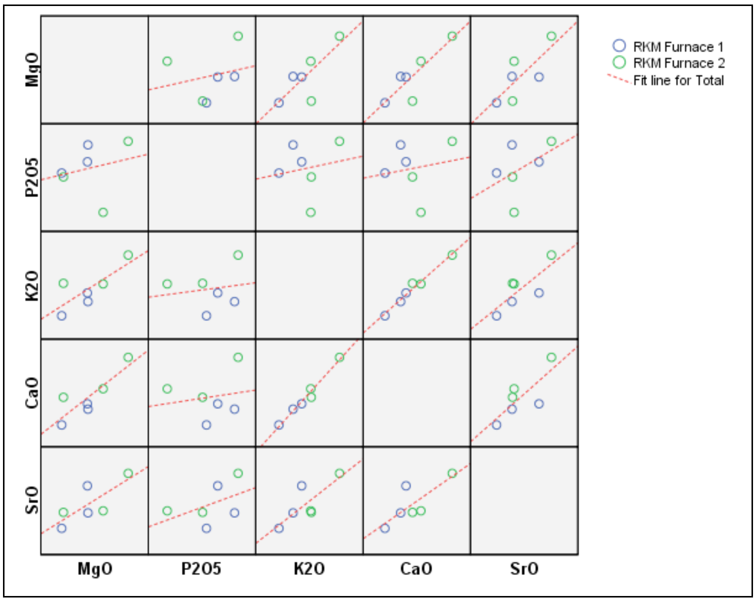


Figure 7.19 Correlations between possible fuel ash compounds in slag blocks from Rukomero calculated from the normalised PED-XRF data presented in Table 6.15

In most of these smelting scenarios, lime seems to be coming primarily from the fuel ash, and judging from the bulk chemical analyses of the slag samples, lime must be present in the fuel ash in relatively high proportions.

Phosphate also appears to be coming with the fuel ash at several sites, except as just mentioned, Rukomero. This counters the common assertion that the presence of phosphate in slag or artefacts indicates that it was coming from the ore that was smelted (e.g. Godfrey *et al.* 2003: 191). The use of fuels with relatively high levels of phosphate may well also have contributed to an improvement in the resulting metal as discussed in Chapter 5.

Roscoe mentions several trees that were favoured for use in Nyoro smelting (1923: 218) – *mirongo, mikola* and *mireme.* The name *mirongo* is of note, as this is also the place name of one of the Mwenge sites. Perhaps this smelting site was located close to where wood for good charcoal was readily available. Charcoal procurement is one of the most labour intensive elements of iron smelting and locating smelting sites close to a source of good charcoal may well have had a labour saving intention. Schoenbrun (1998: 26) asserts that the earliest iron working in the region was necessarily located in regions rich in both iron ore *and* charcoal.

Childs' informant mentions five types of trees that were used to prepare charcoal for smelting in Mwenge, none of them called *mirongo.* Their Lunyoro/Rutoro and Latin names were *omusasa* (a forest edge tree, *Sapium ellipticum*); *omurongo* (possibly the same tree as *mirongo*, a pink-flowered bi-pinnate, *Albizzia grandibracteata* or *A. zygia*); *ekibirizi*; *omuhakwa* (a small, purple-flowering tree, *Millettia* spp.); and *omusoko* ("a common tree in Kibale Forest", *Warburgia ugandensis*) (Davis 1952: 181-184; Childs 2000: 217). *Omusoko* was thought to be the best, but required visiting the forest; all were suitable to be used, and all had their individual characteristics.

The final element concerning fuel to be examined here is the *pattern* of fuel ash contributions within individual smelts. In a number of the individual smelts, including those at Kyakaturi and Mirongo Group 1, it seemed that the fuel ash contribution was greater at the beginning and the end of the smelts. This, taken together with the evidence from the optical microscopy of the slag samples from the bottom of the slag blocks (which showed no tendency towards initial fast cooling in a cold furnace pit), indicates that the furnace pits were pre-warmed as Roscoe had documented in Hoima (1923: 220):

> "Before the smelting was started a slow fire of grass and reeds was lighted in the pit to hasten the drying of the clay and warm the furnace".

Aside from charcoal for fuel, a further use of plant material in smelting constituted that used to pack the furnace – although plants were undoubtedly used in several other contexts throughout the smelting process, to make brushes to daub water on the tuyères to prevent them catching fire, to lift the bloom from the furnace and so on (for example see Figures 7.29 to 7.34, and Childs 2000). Evidence for the former survives in the impressions of plants left upon and within the slag blocks. This choice of plant material was also an important one, yet it is rarely addressed in archaeometallurgical studies (although exceptions include Mikkelsen 1997, 2003; Thompson and Young 1999; Iles 2004, 2009b).

Dominating the plant impressions at all sites were small to medium sized grasses or reeds, although occasionally larger grasses or reeds were used. A number of sites also bore occasional sedge impressions, namely Kyakaturi and Kisamura (and possibly Kirongo), although these were never the dominant plant choice. Rarer still were impressions of *Musa* species and dicotyledonous woody plants (*cf.* Iles 2009b), which occurred only at Mirongo Group 2 and Kisamura (and Birenge, mentioned briefly in Chapter 4). Roscoe's description above of the pre-smelt firing of the furnace specifically denotes the use of grasses and reeds, which would fit with the evidence presented here. Conversely, when describing Ganda smelting, he notes that dry papyrus was preferred to grass for this purpose (1911: 379).

SUMMARY OF TECHNICAL PARAMETERS

In conclusion, the above discussion indicates that there are several patterns in the technical components of these smelting episodes. The use of a fluxing manganese-rich mineral in addition to an iron ore is the most striking technological distinction, which seems to go hand in hand with a slightly decreased technical ceramics consumption. The choice of tree for charcoal production seems to have remained relatively consistent, and the fuel ash generated would have added lime and phosphate (in varying quantities) into the smelts. The methods, materials (including the use of grog temper) and technology of technical ceramics production also seem to have remained fairly similar across the region. The iron-rich ore present at Kyakaturi was effectively dealt with by adding a silica-rich flux to create a slagging furnace charge.

These parameters would have had tangible effects on the relationship between the inputs and outputs of the smelts, most especially the additional presence of manganese oxide. Although measures such as 'efficiency' are culturally contingent as well as dependent on factors of access and resource availability, it can generally be considered within the framework of providing the "highest possible return for their efforts" (Charlton *et al.* 2010: 365). As Charlton *et al.* point out, a key factor that must be considered is the frequency with which ore types are encountered in the landscape. In these cases, if the *entabo* used to supplement the primary iron ore was easily and readily collected from frequent surface deposits, it can be ventured that this was indeed a very profitable technological development; if instead, as Childs (2000: 210) suggests, acquiring this second ore required entering into negotiation and trade from limited locations, then the pay off (in economic terms at least) may not have been as dramatic. The possibility that this extra material was being chosen in order to create iron for objects that required particular toughness and strength (especially as some manufactured objects would have required more flexibility over strength) makes assessing the economic impact even less straightforward. However, the survival of this technology even within twentieth century memory indicates that it was considered a beneficial innovation.

PART TWO: STANDARDISATION AND CONTROL

Iron technology is not static, but is instead a continuing process, constantly in flux and change (Hjärthner-Holder and Risberg 2003: 84). Many accounts of African iron smelting depict these technologies as "hidebound by taboo and ritual, inherently conservative with no tendency to innovate" (Fowler 1990: 37; see, for example, Austen and Headrick 1983); the glaring contradiction this holds with the extensive variation in evidence across the continent is sometimes overlooked (*cf.* also Chapter 3). Issues of ownership, status, craft specialisation, centralisation, knowledge of other pyrotechnologies, and the acceptance of technology and innovation have the potential to make a big impact upon how a technology changes and develops, determining what remains the same, and what will be transformed (Hjärthner-Holder and Risberg 2003:

84-85). The theory and background behind these processes has been introduced in Chapters 2 and 3; this section aims to draw the available evidence from Mwenge together to assess what can be learnt about the organisation of iron production within this localised area through an examination of the variations evident within and between the sample sets.

VARIABILITY

After reconstructing (as much as possible) the technical aspects of the technologies in operation at each site, a further variable was considered. This was the degree of repeatability of the technology, the extent to which the process was being replicated following similar procedures time and time again at each site: an important indicator of the extent to which a smelting site was organised and controlled.

Bloomery iron production is a high-risk investment activity; once the furnace is fired and the smelt is under way there is a lot at stake. Days or weeks of resource procurement and preparation culminate in a single firing that could potentially fail if various requirements have not been met: too much variation from a known and accepted 'recipe' may result in loss (economically, and also possibly of reputation) for participants. Charcoal, seasonality, ore, clays, access to the usual resources, furnace construction, ratio of fuel to ore, weather conditions, experience and energy of head smelter and bellowers are all factors that are liable to change, that have to be accounted for, and which leave their mark on the results of a smelt. Anything that might affect the temperature, atmosphere or ingredients of a smelt might affect the outcome.

However, this does not preclude opportunity for experimentation and innovation. As noted, "pre-industrial iron production is sometimes portrayed as a static and unchanging technological endeavour, except when it shifts to new geological or socioeconomic settings" (Charlton *et al.* 2010: 365), yet Charlton *et al.* and others (e.g. Chirikure and Rehren 2006; Iles 2006; Humphris 2010; Mapunda 2010; Robion-Brunner 2010; Humphris and Iles, forthcoming) are beginning to illustrate the full extent of technological variation and change that would have dominated the pre-industrial iron smelting landscape. The indispensable role of the risk-taking experimenter is played and replayed throughout the history of iron production, leading to invention and innovation, but also, inescapably, occasional failure. The heated discussions between smelters and smiths as relayed to us through Schmidt's smelting reconstructions (1997: Chapter 4) are testament to the complex and personal influences that would be at play at each and every smelt, and what might happen when those discussions and compromises go wrong.

In light of this, the coefficients of variation (CV) of the bulk chemical data of all the slag blocks from the sites presented here were calculated, in order to ascertain the extent to which smelting was standardised at each site, that is to say, how *little* variation was present in the composition of the materials *leaving* the smelt in the slag [9]. The rationale is that this would reflect the degree of standardisation maintained over the ingredients being fed into each smelt. This variation has already been discussed per site individually; it is now drawn together to see if there are any broader patterns. An important consideration here is to remember that the sampling strategy explicated in Chapter 4 aimed to document both the 'normal' slag blocks as well as any unusual specimens; moreover, all samples were included in these calculations, including multiple samples from single slag blocks, further increasing the CV.

Those compounds present in larger quantities tend overall to have lower coefficients of variation (*cf.* Table 7.12, and compare colour coding of trace compounds to major and minor compounds). Iron oxide particularly, remains very steady. Compounds showing the most significant variation are titania, vanadium, nickel and barium oxides. Several sites also stand out as having comparatively low variation – namely Kyakaturi and Rukomero (although the CV from Rukomero is calculated from a small number of slag samples, from a small number of potential smelts). The smelters of Kyakaturi in particular seem to have maintained very constant parameters in their smelts.

[9] At least in the *chemical* aspects of smelting. As there is only a maximum of two furnaces excavated per site, it would be difficult to examine any possible stylistic variation. Neither is it possible to discuss variation or standardisation in the multitude of *in*tangible actions that make up iron smelting as a whole.

	Major and minor compounds (CV %)												
	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO
KTR (n = 14)	21	22	15	13	14	25	17	30	20	25	30	33	8
MNG Group 1 (n = 8)	61	58	11	33	13	39	17	37	14	32	58	39	10
MNG Group 2 (n = 6)	53	76	17	12	42	49	37	54	/	132	51	16	11
MNG All (n = 14)	56	117	24	31	32	45	33	59	92	68	55	74	23
RGB (n = 7)	20	70	31	31	36	25	84	43	64	55	23	73	16
KRG (n = 16)	17	46	17	17	31	23	23	28	53	55	34	16	9
KSM (n = 15)	24	30	15	12	21	30	41	16	117	105	20	25	7
RKM (n = 6)	22	50	18	18	44	29	39	41	15	92	9	9	10

	Trace compounds (CV %)											
	Co_3O_4	NiO	CuO	ZnO	SeO_2	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3
KTR (n = 14)	20	/	31	28	/	35	23	24	35	56	40	85
MNG Group 1 (n = 8)	56	283	63	/	/	34	22	33	50	49	29	50
MNG Group 2 (n = 6)	/	50	88	/	/	72	22	25	62	60	53	75
MNG All (n = 14)	115	234	73	/	/	59	24	55	113	52	43	98
RGB (n = 7)	39	/	90	74	/	56	49	50	112	91	51	44
KRG (n = 16)	/	/	36	/	/	36	22	22	37	43	45	30
KSM (n = 15)	/	/	42	54	56	33	32	22	78	28	26	49
RKM (n = 6)	46	/	48	/	/	28	/	20	60	26	53	66

Table 7.12 Coefficients of variation (%) across the slag samples from each site, calculated from PED-XRF data presented in previous chapters. The number of samples that these figures are generated from is indicated in brackets after each site code. Values equal to or under 25 are highlighted in grey; values equal to or over 50 are highlighted in pink

To examine whether changes in variability (or standardisation) were linked to either time period or charge composition (i.e. Mn-rich vs. Mn-poor), the relevant CVs were averaged and presented visually in Figures 7.20 and 7.21. Interestingly, neither factor stood out as having a significant impact on standardisation, with very similar CVs across all compounds, except for titania and vanadium oxide in the manganese-rich sites (and as such, in the later sites). Suggestions as to how this particular variability might be explained have been discussed in the previous sections. It does appear that later sites tend to have marginally increased standardisation (Figure 7.21), yet this is a very slight difference, and it is not necessarily reliable across such a small sample set.

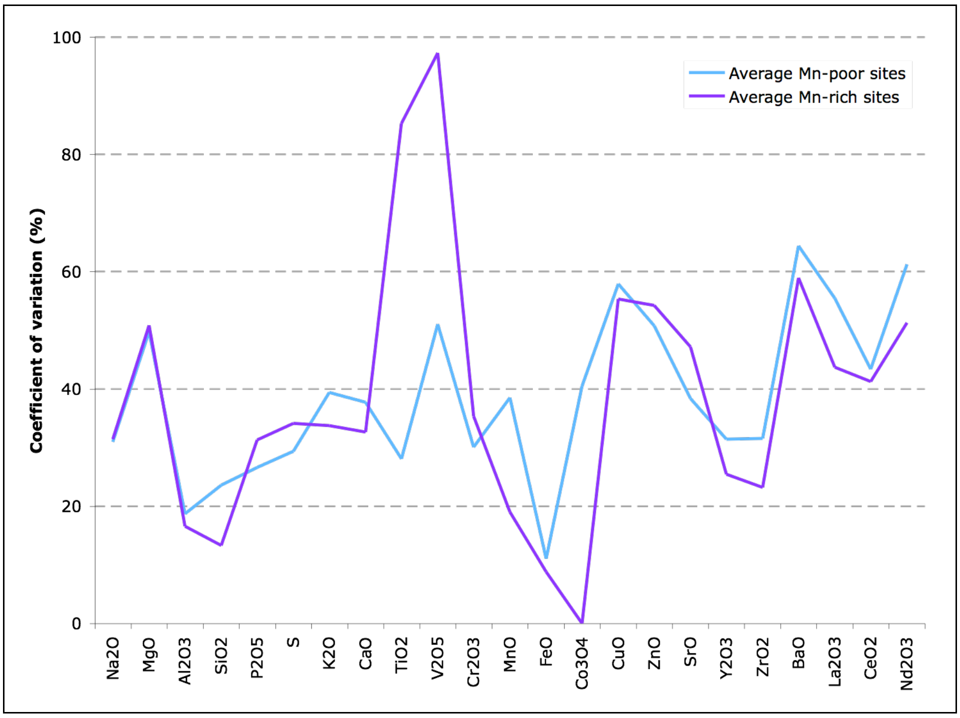


Figure 7.20 Line chart comparing CVs of sites with Mn-poor slag (Kyakaturi, Mirongo Group 1, Rugombe, Rukomero) and Mn-rich slag (Mirongo Group 2, Kirongo, Kisamura)

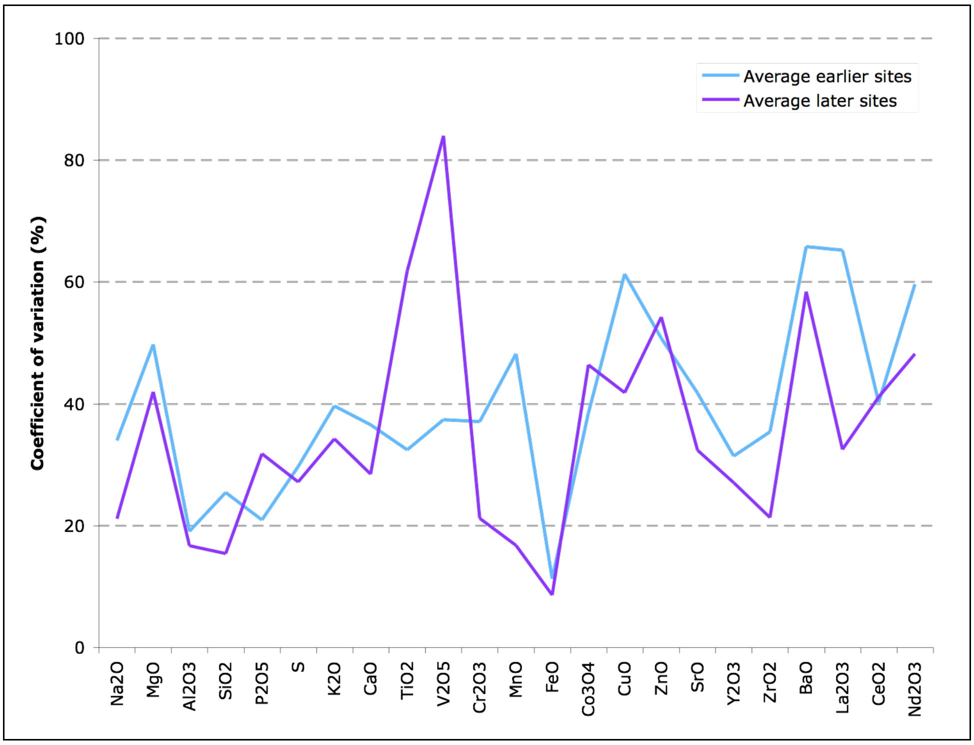


Figure 7.21 Line chart comparing CVs of earlier sites (Kyakaturi, Mirongo Group 1, Rugombe) and later sites (Kirongo, Kisamura, Rukomero)

'Standardisation' as a concept can be (and has been) interpreted several ways. Often standardisation is seen in technologies where there is regular and large-scale production, where a technology has been 'routinised' to maximise efficiency and productivity. Because of this, greater standardisation has tended to be used as an indicator of a more intensified level of craft specialisation, most especially within ceramic production (e.g. Rice 1981, 1991; London 1991; Costin and Hagstrum 1995; Costin 2000). However, ethnoarchaeological data drawn from a variety of production technologies (although with particular reference to ceramic production) have suggested that this is an over-simplified approach to the understanding of the organisation of production, and that there is not necessarily an automatic and reflexive link between increased standardisation and large-scale production (*cf.* Chapter 3; Costin 1991; Arnold 2000; Roux 2003). Conversely, a high level of variation may indicate a period of experimentation and innovation (*cf.* Eerkens and Lipo 2005, 2007; Charlton 2007).

Within these Mwenge sites however, limited variation is apparent. It appears therefore that producer and consumer are both happy to use an established method, with evidence for experimentation and deviation minimal. Nevertheless, one significant variation is the presence of groups of both manganese-poor and manganese-rich slag blocks at Mirongo, and this deserves to be discussed further.

Within this one site, a period of smelting occurs that was dated to approximately the fourteenth century. This technology appears to utilise only iron-rich ore(s). A further period of smelting (indicated by two additional clusters of slag blocks) also occurs that appears to utilise a manganese-rich ore in conjunction with an iron-rich ore. Unfortunately, it is not possible to directly date this second smelting period. Inferred associations with recent ethnoarchaeological data and technical similarities with two later sites (Kirongo and Kisamura) suggest that these clusters of smelting activity may not have been contemporary, and instead the manganese-rich smelting might have occurred at a later date to the smelting associated with the furnace. However, it is equally plausible that these smelts were undertaken by two different (competing?) groups at the same time.

Needless to say, without the ability to directly date the slag remains, the range of possible reasons for this variation is frustratingly large. What can be said – through an appraisal of the CVs for each group at Mirongo – is that these two smelting approaches are unlikely to be related to each other. The results do not suggest that one technology is a development from the other: there is no intermediate range in composition, unlike the 'chemical lineages' identified in medieval bloomery smelting in Wales (Charlton *et al.* 2010) or in Iron Age copper smelting in Thailand (Pryce *et al.* 2010). Within each group, the technology appears to be stable and well controlled. Does this technological difference indicate the arrival of a different group of smelters into the area (*cf.* also Humphris *et al.* 2009)? The close proximity of these two separate traditions (in geography if not necessarily in time) is a tantalising discovery and one that will hopefully be explored further in the future.

Variation within individual slag blocks was also assessed, offering the opportunity to examine the degree of control that was maintained over smelting parameters – air input, furnace charge, structural cohesion and so on – over the course of a smelt (Figure 7.22).

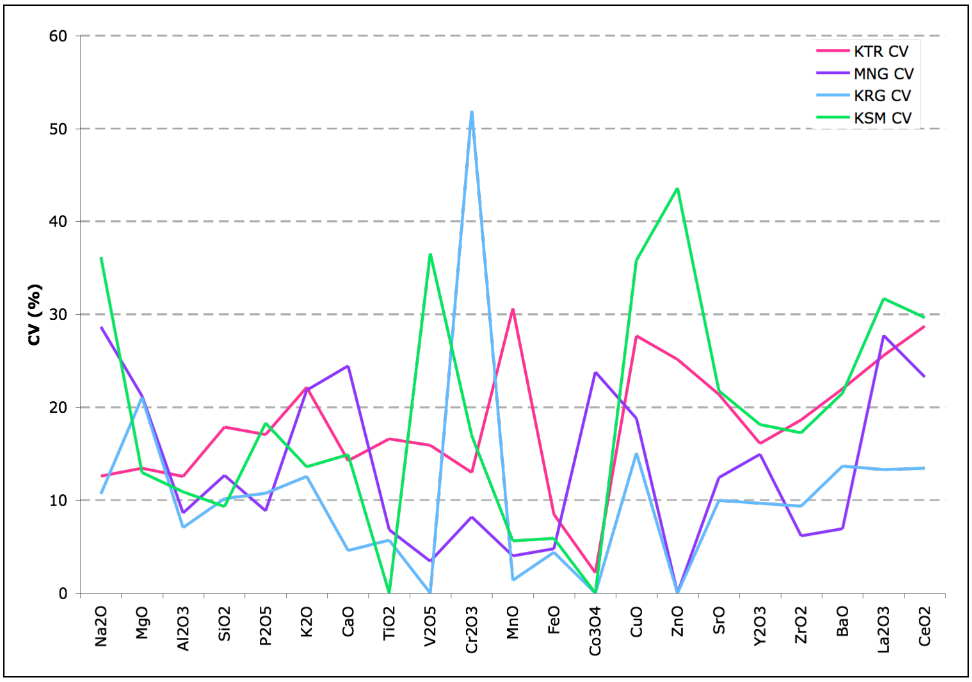


Figure 7.22 Line chart showing CVs of single slag blocks (representing the course of a single smelt) from Kyakaturi, Mirongo Group 1, Kirongo and Kisamura

As with the intra-site variation, the internal variation per smelt was also quite low at all sites examined in this way – they all showed a reasonably low level of variation (generally less than 30%, with some higher CVs in the results from Kirongo and Kisamura), which suggests that smelting parameters remained relatively constant throughout the course of the smelt. Not only does this hint at the execution of a well-oiled semi-industrial process[10], it also fosters confidence in the homogeneity of the slag blocks in general and the representative nature of the remaining slag sample set.

RESOURCE PROCUREMENT

Variation between smelts may occur when access to known resources changes, and smelters lose control over what materials they can use, necessitating experimentation and innovation. Schmidt's Haya smelting reconstruction provides a pertinent example of this: during the reconstruction he commissioned, the site of the preferred choice of clay for the tuyères (situated at the edge of a large swamp a couple of kilometres from the smelting site) had been flooded by heavy rains, rendering the area inaccessible (1997: 62). As such, a secondary (inferior?) clay was used. However, interruptions in the availability of materials may take many forms, not only those that are short term and environmental. Long-term disruption due to political or social power mechanisms may force a permanent and significant impact upon a technology.

How access to the key smelting resources of Mwenge was controlled in the past is largely unknown. However, there are some indicators from the more recent ethnoarchaeological record. The fullest local description of resource procurement is Childs' research regarding the discovery and operation of mines (1998a, 1998b, 1999, 2000). Finding a new mine was a profitable endeavour, so many took part. Several social networks were called into operation during the process of looking for iron ore, related primarily to clan and family. Once found, "the person who discovered a new hill of ore … became its instant owner", or *omujumbuzi* (Childs 1999: 27), and took on important economic and ritual roles in the subsequent procurement of the ore. The

[10] Whilst recognising that equally a 'well-oiled', standardised technology may result in high intra-block CV, for example one that involves preheating.

omujumbuzi allocated work, salary and mining space. If separate groups wanted to also mine that hill, payment would be made to the *omujumbuzi* in either ore or iron (Childs 1999: 30-31; 2000: 205). It appears that nepotism played a considerable role, with the discoverer allocating the richest mining areas to those with the strongest clan or familial links to him (Childs 2000: 209). As all were able to search for ore, this presumably meant that there would be periodic changes in access to good ore by various clan or family groups, as new mines were discovered by those with different affiliations:

> "Membership in a family, clan, village, interclan cadre of ironworkers … determined who was included and excluded from each phase of ironworking and its related activities".
>
> (Childs 1999: 26)

This example, admittedly solicited from a single informant, gives some indication of the social constraints that may have been acting upon groups of smelters in Mwenge, and which may have determined where they obtained the ore that they smelted and of what quality it would be, with possible effects on the outcomes of their smelts.

RITUALISATION

Ritualisation is often posited as a way of maintaining the necessary level of stringent control over risky technological procedures – garnering control over difficult processes and (ostensibly) setting methodologies in stone, as well as providing "buffer excuses" for master smelters in the case of failure (Mapunda 2010: 220). Yet, as previously discussed in Chapter 3, the complexity and variety of the aims, outcomes and conceptualisation of ritual prevents such a neat summation. African iron smelters were not "automaton[s] reproducing technical steps with the aid of ritual mnemonics" (Fowler 1990: 37); rituals took many forms, were derived from many sources, and functioned through numerous mechanisms to achieve a number of aims.

However, ritual elements are known to have been implemented in at least some iron production technologies in Bunyoro and western Uganda (*cf.* particularly Childs 2000), as well as the wider Great Lakes region and sub-Saharan Africa as a whole. They have more usually been documented ethnoarchaeologically (*cf.* Chapter 3), but some – those more tangible and materially robust, such as plant remains, medicine pots and so on – have also been documented archaeologically (e.g. Wyckaert 1914; van Noten 1983; *cf.* Schmidt and Mapunda 1997).

No direct material evidence for ritualisation was encountered in Mwenge. The bases of all of the excavated furnaces were dug through to confirm the presence or absence of further remains, such as buried deposits. However, despite no ritual pits being found, it is possible that some extent of ritual would have surrounded these technologies. Roscoe (1923) is explicit in his descriptions of the ritual behaviour that surrounded Nyoro work of *any* kind, and Childs provides extensive descriptions of the ritual behaviour and associations that surrounded mining, smelting and smithing from her informant in Mwenge (Childs 1998a, 1998b, 1999, 2000). Furthermore, there were some archaeological indicators that iron smelting in this area may have had its own set of ritual activity in the past.

First, the (at least) more recent association of the ore(s) with genders is indicative of a continuation of a wider practice of attributing gender and reproductive qualities to substances, materials and people, classifying and conceptualising them as hot or cold, dry or wet, male or female. This worldview visualises the world according to these categories, and necessitates that strict social rules respecting these categories are followed for work to be successful. If a mixing of two ores can be linked with this approach (which is not necessarily the case), then this may reveal a means of organising production systems that extended at least some way into the past.

Second, the use of kaolinitic clay may not only have had a practical function. We know that kaolinitic clay was specially mined for a variety of purposes in neighbouring Buganda – medicinal, ritual and technological (Badenoch 2004). A particular feature of kaolinitic clays (aside from their refractory qualities) is their whitish colour. White has a symbolic association in Buganda and Bunyoro, as well as in Nkore, Rwanda and Karagwe. Doyle (2007) asserts the association of white (spirits) with notions of purity, goodness and indigeneity. Childs also mentions the colour white as a symbol of "purity and luck" for Banyoro and Toro people, and mentions several occasions when the colour white was appropriated within an iron smelting context (Childs 1998a: 128-129). At the opening of new iron ore mines in Mwenge, a white sheep was slaughtered, roasted and feasted upon, the skin of which was made into a protective item of clothing for the iron workers (*cf.* also Childs 1999: 36), as well as being used for the bellows. Furthermore, she adds "the iron produced in a successful smelt was called 'white'", and that "a Toro song… refers to the smith's hammer as 'white'." Her informant, Ndunga, told her "that something that is white is what is good. The iron that will out will be white. All that will come from that ore will be white. That is why they always slaughter white sheep" (Childs 2000: 205).

Within the north of Bunyoro, Roscoe repeatedly mentions white clay as being used in association with "special purification and fasting", especially with the herders who looked after the kings sacred cows, virginal milk-servers and the royal cook (1923: 96-102, Plate VIII *cf.* Figure 7.23), and other purification ceremonies regarding the coronation of the king (1923: 128) or the birth of twins (1923: 164). Although not linked to iron working directly, this reinforces the ritual significance of white and its connection to a notion of purity.

Figure 7.23 Photograph of milk being presented to Omukama Duhaga II by milk-servers with faces and bodies painted white with kaolin. Photograph by Rev. J. Roscoe, reproduced courtesy of the Cambridge University Museum of Archaeology and Anthropology (CUMAA, P.39100.ROS)

Throughout the Great Lakes region, kaolin seems to have an association with pregnancy and childbirth (*cf.* Badenoch 2003) – again associating the furnace and the smelt with another facet of reproduction, and creating parallels with the oft-recorded perception of the furnace as a womb giving birth to a bloom of iron (*cf.* Herbert 1993; Schmidt 2009).

Third, the seemingly intentional deposit of a panga at the site of Kisamura is very suggestive. Its horizontal position within the pit in which it is buried implies that it was placed there carefully rather than discarded thoughtlessly. Although I can find no other reference to similar depositions, it is probable that burying an iron object in such a way is connected to the value that is attributed to that object, its function and the material from which it was made. The practice of throwing keys and other metal objects into deep pits is known elsewhere in the region, for example at Kako (A. Reid pers. comm. 2010), though no studies of this phenomenon have been carried out.

Ultimately, inferring ritual aspects from the archaeological remains of iron producing technologies is often uncertain. For example, the empty 'ritual' pits identified by Schmidt (1997) in several furnaces at the KM2 site in Buhaya may equally be a remnant of the method of furnace construction (*cf.* Humphris 2010: 41, Figure 2.5). Extreme care is required in the interpretation of any such feature. Nevertheless, it remains that some function of ritual (although not necessarily all) may well relate to the repeatability of the technical processes, and may have provided some level of control over technical parameters, reflected in the low CVs of the slag compositions within sites. The time depth provided by these sites is also limited, and as such there is not very much that can be concluded regarding the ritual elements we see in the ethnoarchaeological record and how far back they stretch in time.

PART THREE: STRUCTURES AND STYLE

FURNACE SHAPE

When all the furnace profiles were brought together (Figure 7.24), it was clear that they were all very similar in size and shape (except for Kisamura, which was both highly eroded and seemingly unusual for the area). The overall similarities were highlighted when compared with two of the furnaces excavated in the other areas – the site of Kisengya to the north in Masindi district, and the site of Kiwesi to the south in Kooki (which would now be considered part of Buganda).

Depth (although potentially affected by variable preservation) was the largest variable in the Mwenge pit furnaces shown below, ranging from 30cm at Kyakaturi and Kirongo to 60cm at Rukomero. Diameters were more regular, ranging between 50 and 70cm. Controlling the atmosphere in a bloomery furnace with an oversized diameter is a difficult task (*cf.* Schmidt 1997: 85-86), so it makes sense that these furnaces tended to have diameters of less than a metre.

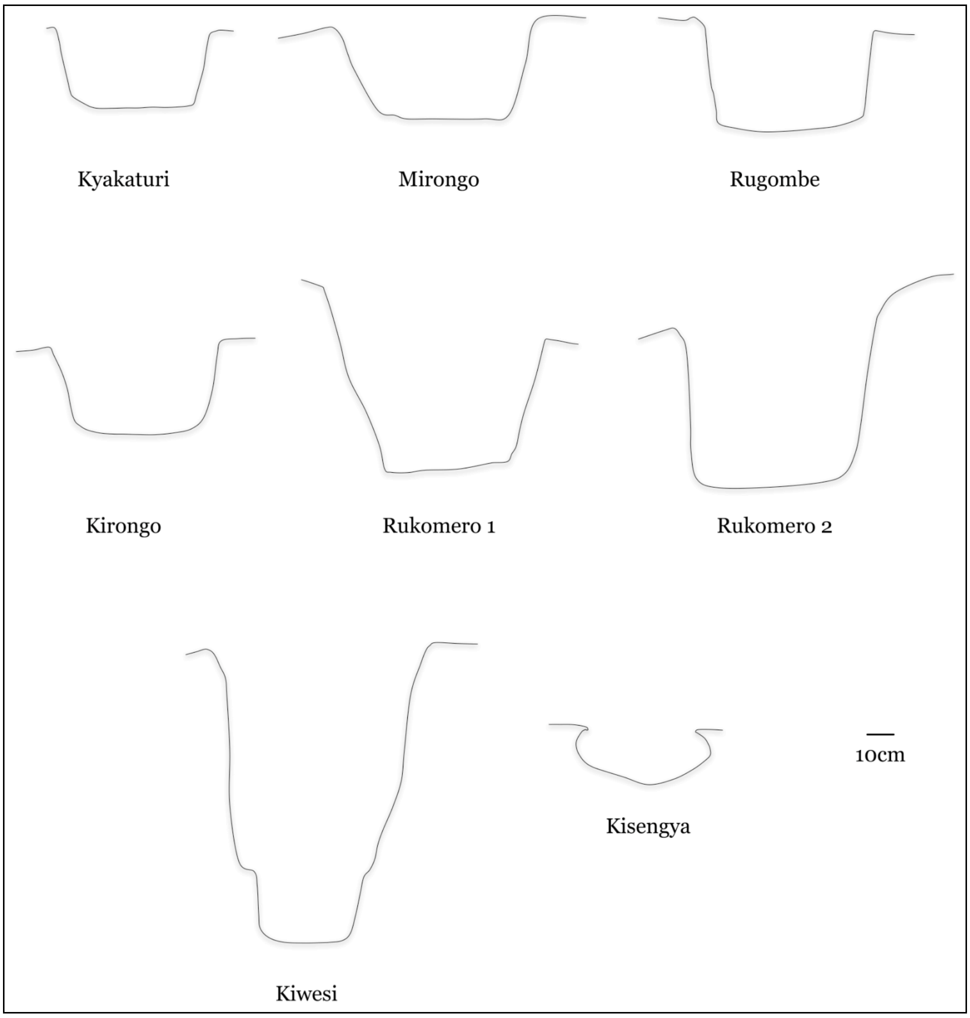


Figure 7.24 Section drawings of all excavated furnaces from Mwenge (except Kisamura, top rows), alongside profiles of furnaces from Masindi and Kooki for comparison (bottom row, *cf.* Appendices A and B)

The peculiar (and repeated) shape of the slag blocks from Kisamura and Kirongo may indicate a particular design of furnace construction at these sites, with air fed into the furnace from only one side (Figure 7.25). This configuration would have encouraged the slag and bloom to form towards one side of the furnace.

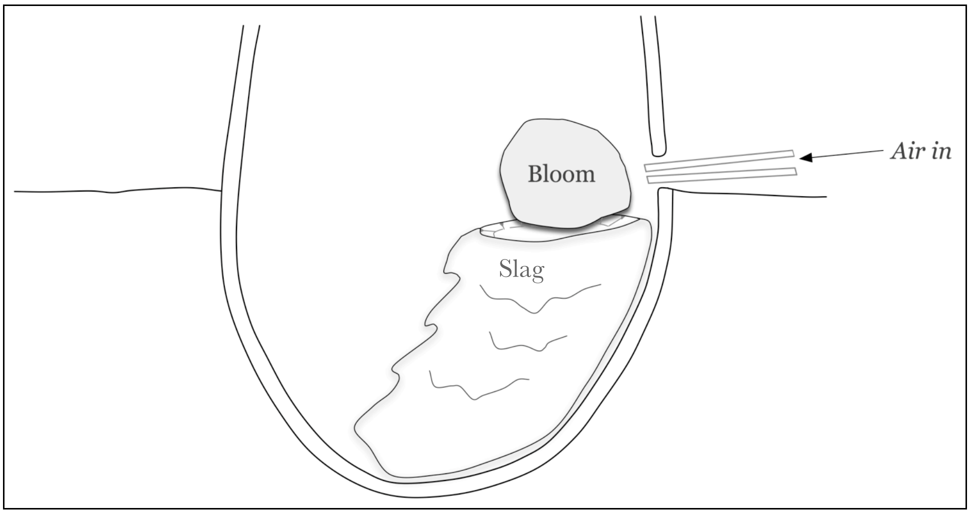


Figure 7.25 Schematic diagram of bloom and slag formation in a pit furnace utilising a single tuyère (not to scale)

The use of a single tuyère is a feasible proposition, witnessed ethnographically and inferred archaeologically (e.g. Jeffreys 1952; Fowler 1990; Crew and Charlton 2007 amongst many others; see also Rehder 2000). Mafa smelting was also operated through a single tuyère (David *et al.* 1989), although this was a very different technology than that proposed here. The furnace at Munsa (*cf.* Chapter 2, Figure 2.6) is also thought to have used only one tuyère.

Apparently in support of this suggestion is the presence of a 'lip' seen only on one side of the furnaces at Mirongo (Figure 7.26), Rugombe (Figure 7.27) and Kirongo (Figure 7.28). I believe that this may be attributed to preferential attrition of the furnace pit lining close to the single tuyère nozzle. Schmidt (1997: 184) noted attrition of furnace lining that seemed similar in form to the 'lips' described in earlier chapters. These sites, with the exception of Rugombe, are also sites with very limited frequency of tuyère remains. Robertshaw also states that tuyère fragments in general were rare during his survey across four areas of western Uganda (Robertshaw 1994: 114).

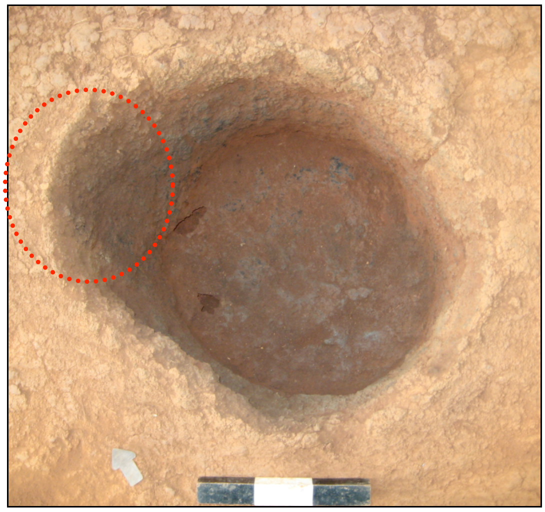


Figure 7.26 Excavated furnace base at Mirongo ('lip' marked with red dotted line)

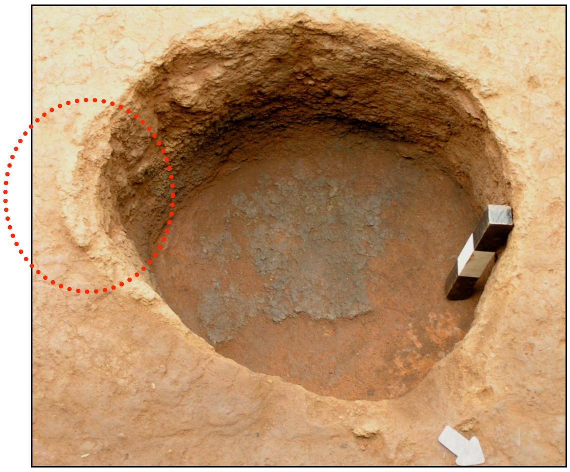


Figure 7.27 Excavated furnace base at Rugombe ('lip' marked with red dotted line)

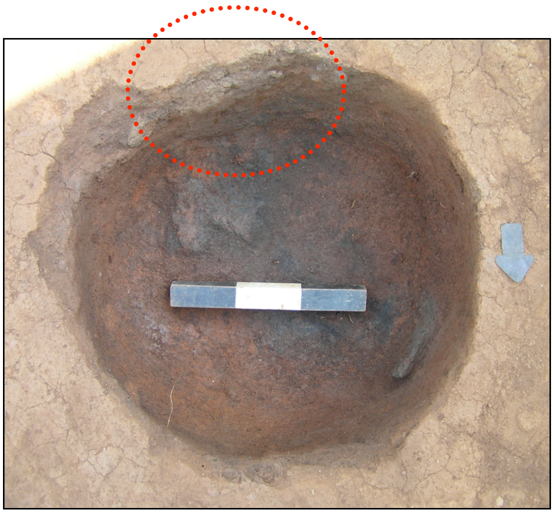


Figure 7.28 Excavated furnace base at Kirongo ('lip' marked with red dotted line)

The furnace at Kisamura seems both anomalous to the furnace blocks associated with the site *and* the other furnace remains in Mwenge. As discussed in Chapter 6, the remains are not distinct enough to draw strong conclusions about the nature of this structure; further fieldwork to identify similar features is required.

The effect that these differences in furnace construction would have had upon the smelts was considered, including whether the introduction of air from one side of the furnace only would have had a discernable impact on control of the reducing atmosphere within the furnace, or whether there was any correspondence between this and a more limited volume of ceramic material contributing to these smelts. The first question referred back to the internal homogeneity of the slag blocks, but no clear difference was seen between the CVs of the single slag blocks at Kisamura and Kirongo as compared to those at Kyakaturi. The volume of ceramic material consumed by the smelt also did not seem to be greatly affected by this design aspect (see this chapter, Part One, Technical Ceramics). However, one important point to consider is that if this *is* attrition from the positioning of a tuyère, the original depth of the furnace pit can be inferred.

ETHNOGRAPHIC DESCRIPTIONS

Ethnographic descriptions of furnace design exist from three areas of western Uganda – Childs' and Buchanan's descriptions of smelting in Toro/Mwenge, Roscoe's (and Cline's) description of the royal smelters of Nyoro (probably in Hoima), and Roscoe's and MacLean's descriptions of (Ganda) smelting in Mpigi/Buddu. Of the two accounts from Mwenge, one (Childs) seems consistent with the suggestion of the use of a single tuyère, and one (Buchanan) suggests the use of multiple tuyères.

Childs describes a furnace pit one metre in diameter and one metre deep, lined with ash and with a protective shelter built over it. One pair of bellows was placed at the side of the furnace, with a tuyère set into the pit, leading into the furnace just above the layers of dried reeds and charcoal, and below the layers of charcoal and ore.

There were no walls or superstructure as there was in neighbouring groups (Childs 1999: 31-32).

This description seems to correspond very closely with the excavated furnaces and slag remains at Kirongo and Kisamura, and to a lesser extent, Mirongo and Rugombe. These sites at the core of the research area bore strong comparison to this configuration, being similar in diameter and depth, and with indications (either in the furnace or slag remains, or both) of the use of only one tuyère.

Buchanan's informant describes a seemingly different style of furnace in Mwenge, with even some possible intimations of slag-tapping (although no evidence for tapped slag was found throughout the entirety of the survey zone across Mwenge or western Uganda in general[11]):

> "First they prepared burning charcoal and prepared the bellows. Then they dug shallow pits, placed stones around and covered them with charcoal. Then they thatched an enclosure about six feet in diameter. The whole pit was then surrounded by six or seven bellows. People worked at these bellows night and day…
> As the stones [ore] were extracted, they were smelted. They would intersperse a layer of iron and a layer of charcoal in the smelting pit. Then they would cover it with a thin layer of soil. They would also surround the pit with charcoal fire and fan the flames with the bellows. When the heat was intense, the ore would melt and the metal would run down little channels or trenches. When the smelting was finished, the slag would be thrown away. This process takes four or five days."
>
> (Buchanan 1974a: 103)

Roscoe (1923: 220) describes a seemingly similar style of furnace further north, in Hoima. This smelting furnace was a round pit, between 45 and 60cm deep and 45cm in diameter. He describes that the pit was lined and covered with clay, with a hole in the 'lid' that served both as a chimney and an opening through which to feed the charge through. Four tunnels, cut into the ground at an angle, entered the pit approximately halfway down, and 'blast pipes' (tuyères) were set into these tunnels to provide the furnace with air from bellows. Cline (1937: 47) adds that the pit was

[11] Although tapped slag is in evidence at the site of Masaaba, in nearby Buganda (*cf.* Humphris 2004; Humphris *et al.* 2009).

demolished after smelting. This description might correspond with a furnace excavated at Kisengya (*cf.* Figure 7.24 and Appendix B), which appeared to comprise a small furnace bowl with a lipped hood extending over the main bowl of the furnace, although there is a slight difference in dimensions.

Roscoe took a number of photographs of smelters in action whilst he was in Bunyoro, which are now held in the photographic collections of the Museum of Archaeology and Anthropology in Cambridge. Several are reproduced in his 1923 book *The Bakitara* and in *The Northern Bantu* (1915). Although these photographs are technically poor, lacking detail and focus (although the photographer's job is made more difficult by the smelters choice to sit in the shade out of the bright, presumably hot sunshine), they do indicate the diminutive size of the furnaces themselves and the age range of those who took part. Many young boys are present bellowing and watching. However, the clay lid (or indeed, any furnace structure) that Roscoe describes is unfortunately not clearly visible in any of the photographs from *The Bakitara* series (Figures 7.29 to 7.33). However, one photograph, labelled "Banyoro smelters" from *The Northern Bantu* may illustrate this furnace structure, although once more, the photograph quality is poor, and it is difficult to make out any detail (Figure 7.34).

Figure 7.29 Photograph entitled "Iron workers in camp" on back of photograph ('smiths' crossed out). Caption of similar image in Roscoe (1923) Plate XXVI is captioned "Iron smelters preparing furnaces for smelting". Photograph by Rev. J. Roscoe, reproduced courtesy of the CUMAA (P.39090.ROS)

Figure 7.30 Photograph entitled "Smiths bellowing", but caption in Roscoe (1923) to Plate XXVI indicates that these were smelters at work. Photograph by Rev. J. Roscoe, reproduced courtesy of the CUMAA (P.39093.ROS)

Figure 7.31 Detail of photograph depicting same smelters as in Figure 7.30, with clear view of the furnace close to the centre of this cropped shot. Photograph by Rev. J. Roscoe, reproduced courtesy of the CUMAA (P.39094.ROS)

Figure 7.32 Detail of young bellowers in background of photograph depicting potters. Photograph by Rev. J. Roscoe, reproduced courtesy of the CUMAA (P.39104.ROS). See also similar image in Roscoe (1923) Plate XXVIII

Figure 7.33 Two frames reproduced in Roscoe (1923) Plate XXVII depicting iron being levered out of the furnace with tree branches (above) and iron being immediately cut into small parts for smithing whilst still hot (below). Photographs by Rev. J. Roscoe, reproduced courtesy of the CUMAA (P.182125.ROS and P.18217.ROS)

Figure 7.34 Photograph entitled "Banyoro smelters". Photograph by Rev. J. Roscoe, Plate II (Roscoe 1915)

A type of *open* bowl smelting with similar dimensions to the Kisengya furnace has been documented in Kenya by Jean Brown, found commonly throughout much of the country (Brown 1995: 45-46). Illustrated examples are reproduced below (Figure 7.35), showing Embu and Mbeere furnaces (1 and 3 respectively) and Kikuyu smelting in an elongated furnace pit (2). Smelting pits of similar dimensions have also been excavated on the Laikipia Plateau in the central Kenyan highlands, provisionally associated with pastoralist smelters (Iles and Martinón-Torres 2009; Iles and Lane, forthcoming). In Rwanda, van Noten witnessed the reconstruction of an open bowl smelting technology at Gisagara (van Noten 1983; 1985).

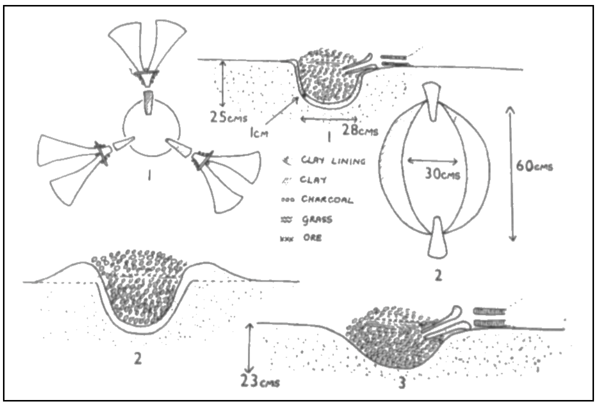


Figure 7.35 Plans and sections of examples of bowl furnaces found in Kenya. 1) Round clay-lined Embu furnace with three tuyères; 2) Oval, clay-lined Kikuyu furnace; 3) Unlined Mbeere furnace. Reproduced from Brown (1995: 47)

In conjunction with the variation in furnace design across Mwenge, stylistic variation is also suggested as occurring in bellows design, although no material archaeological evidence exists for bellows. However, it can be assumed (from the internal diameters of the tuyères present at these sites, and the nature of the pit furnaces) that bellows were indeed used in Mwenge (Pleiner 2000: 198). Roscoe's account of smelting in Bunyoro describes clay pot bellows about 25cm in diameter, covered with goatskin, with a stick attached to the middle with which to raise the goatskin up and force it down again thereby propelling air into the furnace. "The nozzles of two pots were attached to each [of the four] blast-pipe[s] [tuyères], and one man, sitting between two pots and raising the sticks alternately, was able to keep up a constant blast" (Roscoe 1923: 220).

Childs (1999: 27) also makes reference to bellows, which (along with tuyères) were made only by men (unlike other pottery, which was made by women). As there was no furnace superstructure on which to express, communicate and reinforce social values (as seen in many other smelting technologies of sub-Saharan Africa, *cf.* Childs 1991; Schmidt 2009), bellows pots appear to have been used for this purpose instead (Childs 1999: 32-33). One bellows pot was female and the other male, continuing the reproductive theme of the technology (Childs 1998a: 132; 1999: 33; 2000: 214). Lanning (1954) notes the representation of female genitalia on examples of Nyoro bellows; Childs (1999: 33) records that male bellows in Mwenge were sometimes formed to resemble a penis, but suggests also that significant stylistic variation occurred in the decoration of the bellows pots across the area. The male bellows pot that Childs' informant Ndunga describes is inscribed (using plaited papyrus) with a rouletted decoration "like the y-pattern", mimicking male body scarification and with a navel marked upon it. The female bellows pot was decorated with a breast (Childs 2000: 212, 215-216).

In summary, although the use of a moderately sized furnace pit was consistent in all of the excavated furnaces in Mwenge, with many bearing some concordance with Childs' descriptions, both the technical analysis and the ethnohistorical data suggest a level of technological variation in iron production technology across the research area.

So why is there this variation across the wider survey area? What is interesting are the possible cultural relationships between the various iron smelting 'traditions' identified here. The Nyoro smelting documented by Roscoe is possibly strongly linked with a 'royal tradition' of smelting, practiced in association with the kings court, although no reference was made to this (*cf.* also Giblin 2003, who discusses the royal potters of Buganda). Most of the time Roscoe spent in Bunyoro was in Masindi, but he was invited to spend a month in Hoima – the *omukama*'s home town, and the site of the old capital – where re-enactments of the New Moon ceremony and other traditions were displayed for him (Deane 2007: 37). It is likely that this is also where the traditional crafts that he recorded – including the iron smelting and pottery that he photographed – were exhibited. The only excavated furnace that seemed comparable to this description was that excavated in the northern survey area at Kisengya (*cf.* Figure 7.24 and Appendix B).

Buchanan's record of a similar type of furnace in Mwenge is intriguing. However, no similar small pit furnaces to that found in Kisengya were found in Mwenge – if such a technology *was* also practiced there, why were no remains found? Perhaps they were all destroyed, as Cline suggests. Perhaps due to their small size and depth they survived less well in the archaeological record. Perhaps their small size made them harder to spot; the feint traces of the larger furnaces were difficult enough to detect anyway (*cf.* for example Figure 6.5).

It is of possible relevance that the two accounts of Mwenge smelting originate from two different clans renowned for iron smelting. Buchanan (1974a: 102) recounts a Muganda informant – C. Kisosonkole, living in Mwenge – who said:

> "In the long past there were not many cattle in Mwenge. People such as the Basita and Bachwamba did other things like ironworking."

Childs' informant, Ndunga, was of the Bachwamba clan, and traced his family to Ankole (Childs 2000: 199). He himself is recorded as saying: "They [smiths/smelters] did not come from the same clan. Some were from other clans and they had their own gods [abachwezi]." On the other hand, Buchanan's informant, Winyi (who communicated the previous description of a Mwenge smelting furnace), was a Musita, the Basita being a large clan associated with iron smelting that is widely dispersed across western Uganda and the wider Great Lakes region as a whole (Buchanan 1974a: 94, 102). Indeed, Buchanan suggests that this 'pattern' of smelting developed in Mwenge, but was linked to the Basita.

Conversely again, the excavated furnace pit from Kiwesi (meaning 'the place of the smiths') in Kooki appeared to be yet another style, with a significantly deeper pit (*cf.* Figure 7.24 and Appendix A). Of relevance perhaps was the fact that those who lived in Kiwesi traced their family histories back to Bunyoro, perhaps attributing a further technological style (one much closer in furnace design to that seen at Rukomero) to the wider Bunyoro region.

Nevertheless, although our knowledge is as yet limited, it seems plausible that some of these nuances of style may be related to clan affiliation, and the presence of some very detailed clan histories from western Uganda (Buchanan 1974a; and *cf.* Chapter 2) offers the interesting possibility of exploring this further in the region (although not within the limitations of this thesis). As described in Chapter 2, the structured clan-landscape of the Great Lakes transcends both modern-day political borders and the configuration of the second millennium kingdoms. It operated in one way as an extensive system of networks of "contacts, exchanges, and movements" as well as maintaining "ancestral vocations" associated with specific clans, including certain production industries (of which iron is one) as well as other social and economic roles (Chrétien 2003: 90-94).

The influence of such clan ties has been discussed earlier in Childs' accounts of iron ore mining, and related discussions are often introduced to debates regarding the transfer (and protection) of technological knowledge in ironworking contexts across sub-Saharan Africa (e.g. Herbert 1993: 26). As such, it is feasible that clan affiliation had a strong influence on technological style in this region: what Buchanan terms the 'Mwenge pattern of smelting' might be more appropriately considered in terms of a *clan-based* pattern of smelting, with knowledge communicated primarily along clan lines but allowing room for local experimentation and, if the modern ethnographic record can inform us of past practice, also providing the possibility of non-clan based participation.

PART FOUR: SUMMARY

This chapter has served to discuss and compare the analytical results presented in the previous two chapters in conjunction with the ethnographic data from this region. Overall there appear to be variations and consistencies in the combined archaeological and ethnohistorical data, both in Mwenge and in the wider Kitara region. Variations in style, ore procurement and fluxes are matched by continuities in temper, clay procurement and terminology. All of this comes together within localised small-scale industries that are executed in a relatively standardised manner.

A variety of ores were used in the smelts across the region, but of most interest is the use in some smelting clusters of a manganese-enriched material in addition to an iron ore. This technique, which seems to occur more frequently in the later sites, is likely to have improved the ease by which iron was won from the ore. Furthermore, some modern technical accounts concur with implications in the ethnographic record that the use of such a material may have imparted qualities of strength and toughness to the iron that was produced, although our knowledge of the behaviour of manganese oxide in bloomery smelting is not as extensive as it could be. Significant levels of lime were also entering the smelts, usually deriving from the fuel ash. This additive would also have encouraged a slag to form, facilitating the progression of the smelts.

Technical ceramics were consistently made from refractory kaolinitic clays tempered with grog and quartz. In several instances it appears that only one tuyère was used in each smelt; this would have put considerable weight on the single tuyère and bellows to remain structurally stable throughout the smelt in order to maintain airflow. If this feature corresponds to the furnace that Childs describes, it is possible that these singletuyèred furnaces did not have a superstructure. Childs suggests that without the furnace body, social and ritual functions were attributed to other parts of the smelting process: perhaps in these cases white kaolinitic clays and anthropomorphised bellows took on symbolic and meaningful roles that are more difficult to tease from the archaeological record. Smelters to the north and other Mwenge smelting groups (i.e. those at Rukomero and Kyakaturi, and those producing the concave slag blocks at Mirongo Group 2) seem to be using a different technique, but one that was just as effective from a technical viewpoint.

Although there was variation in technological style across the region, most smelting groups that were investigated were producing iron in a standardised and replicable manner, comfortable with their technique and approach. Yet these technological strands have yet to be drawn together to examine the role of western Ugandan iron in the trajectory of the Great Lakes. The following chapter will provide an account of these technologies that considers also the broader political and social, economic and environmental contexts within which they operated.

CHAPTER 8

SUMMARY AND CONCLUSIONS

At the beginning of my research into this subject, I came across the following, rather ominous paragraph. In the first chapter in his book on the saltworks at Kibiro – another of Bunyoro's most significant precolonial industrial centres – Graham Connah declared that:

> "so far as Bunyoro was concerned, an investigation of ironworking was certainly one of the options considered when planning the present project. It was rejected for two reasons, although there is no doubt that it would provide an effective focus for a future research project. First, it would require the discovery of undisturbed iron furnaces, relatively small, discrete features that are often badly damaged or at least deprived of some of their associated stratification by the time that they are exposed by erosion … Secondly, for practical reasons, and in Africa ritual reasons also, traditional iron-smelting has tended to be isolated from normal domestic settlements; therefore cultural material at a furnace site maybe limited and it may prove difficult to relate the technology to the society to which it belonged".
>
> (Connah 1996: 4)

Begun exactly ten years after the publication of Connah's monograph, this PhD research has successfully demonstrated that furnaces *can* be located in western Uganda that retain valuable technological information, despite erosion. I hope that it has also demonstrated that important socio-economic insights can be gleaned from ironworking sites *despite* their lack of association with domestic remains. Although by no means a complete reconstruction of Mwenge's iron smelting technologies, and although there remains much potential for future work and further insights into this industry, I believe that this thesis has illustrated and reinforced the high value of an archaeometallurgical approach to precolonial iron production in western Uganda and the Great Lakes.

The final chapter of this thesis serves two aims. First, the research carried out and described in detail in the preceding chapters will be summarised and contextualised, bringing to life the archaeometallurgical reconstructions by placing them within the social and economic settings described in Chapter 2. Second, the research itself will be assessed and critiqued, and placed within its own social, economic, political and academic settings, and aspects of the research that have relevance within a wider academic sphere will be highlighted. Contained within this will be an exploration of future directions, outlining the elements of this research that could and should be taken further as forthcoming work is developed in order to build a more complete picture of the work of iron producers in precolonial western Uganda.

PART ONE: MWENGE IRON WITHIN WESTERN UGANDA AND THE GREAT LAKES

A large body of data and interpretation has been presented in the preceding chapters, and I now hope to place these findings within a broader social context to tell a more human story of the production of iron within this part of western Uganda. Unfortunately, as there is such a small volume of extant research regarding this topic, the resolution of this story is necessarily limited. However, through this undertaking – pulling together the archaeometallurgical data generated by this research in conjunction with the ethnohistorical and archaeological data – a number of important questions have been raised which will hopefully stimulate and guide future research in the region. A chronological depiction of iron production in Mwenge – as much as can be reconstructed at this time – follows.

CONTEXTUALISING IRON PRODUCTION, 14TH – 15TH CENTURIES AD (1290-1450 cal. AD)

Although the sites to be discussed within this section – Kyakaturi, Rugombe, and Mirongo – fall broadly within what might be termed the Middle-to-Late Iron Age, they join the furnace at Munsa to comprise the *earliest* radiocarbon dated examples of iron smelting found so far within western Uganda. This is not to say that what might conventionally be called Early Iron Age smelting remains (i.e. pre-800 AD) will not be discovered in this region in future studies (especially considering the presence of at least some EIA pottery across western Uganda, *cf.* for example, Figure 6.79). However, the existing archaeological data currently indicates that population density at this time is likely to have been very low (*cf.* Chapter 2), which in turn probably means that local demand for early iron production would also have been limited; the high input costs of iron smelting and the expertise needed to undertake the technology may have meant that producing iron locally was not a viable endeavour in this period. The exotic items found in eleventh to thirteenth century burial contexts at Munsa indicate that complex trading networks were in operation by at least the eleventh century in a region not too far from Mwenge (approximately 90km away). Perhaps similar trading networks also brought iron products into Mwenge and beyond from the prolific early iron producing regions to the south and southeast of these frontier communities (for example, Rwanda, Burundi and northwestern Tanzania) prior to the second millennium AD and the establishment of a vernacular industry in the research area.

However, the linguistic evidence and the palaeo-environmental evidence from nearby Kabata swamp tell a different story. Together they suggest a rise in forest clearance, farming and ironworking in the wider region around Mwenge from around 500 BC, in conjunction with an influx of Sudanic-speaking populations from the north (Schoenbrun 1993a, 1998; Taylor *et al.* 2000). If significant numbers of people *had* arrived in western Uganda at this time, iron would most likely have been an important material to those pioneer groups forging out a living in previously heavily forested areas. Although archaeological evidence for these communities is so far lacking, the future discovery of EIA furnaces in these resource-rich areas would not be implausible, especially towards the Rwenzori Mountains to the west. Only time and more research will tell which of these rather contradictory stories is the more likely.

Moving later in time, towards the middle of the second millennium AD, the earliest furnaces that this research encountered (at the three sites of Kyakaturi, Mirongo and Rugombe) are likely to have been in operation during a period of great change in western Uganda (*cf.* Chapter 2). By now, the region was experiencing increasing aridity and political upheaval, with drier areas, such as Bwera – 100km to the southeast of Mwenge – being particularly hard hit. The major settlement sites there (Ntusi, Bigo) were beginning to fall into decline as people (especially those investing in agriculture) moved in search of more amenable environments, social and climatic. In areas to the north of the Katonga River – Singo, and probably also Mwenge – farming settlements were growing in number and size, evidenced by the emergence of the sites of Kasunga and Kibengo, and the construction of the earthworks at Munsa.

Unfortunately, the poor resolution of the pottery sequence for western Uganda means that it is impossible to determine how many of the sites found during the 2007 survey were attributable to this period. Yet going solely by the data available from these three excavated smelting sites it is possible to suggest that there was a reasonable population of iron users stimulating iron production in this region at this time. A conservative estimate of the amount of iron produced at Kyakaturi – approximately 1400kg – suggests that it would have provided enough iron to forge almost 300 hoes (if one hoe is taken to consume approximately 5kg of bloomery iron, *cf.* Humphris 2010: 299); a more generous estimation, taking into account buried slag bocks and nearby piles of slag to guesstimate 50 smelting episodes over the course of the site's operational life, would reckon the production of up to 800 hoes.[1] This would be more than enough to

[1] Kyakaturi was chosen for this mass balance estimation due to the presence of a feasible ore sample and a reasonably large number of slag blocks. A crude mass balance estimates that for every 100 units of slag produced, 100 units of iron were also produced. This supposes that given the slag composition (50wt% iron oxide, 30wt% silica (primarily from the silicate flux) and 20wt% 'other') and ore composition (90wt% iron oxide and 10wt% 'other'), two measures of ore are required to match the proportion of 'other' left in the slag (if contributions of 'other' from ash and technical ceramics are ignored). This gives 180 units of iron oxide, 50

keep a local farming population going for a while, and may well also have fed into wider trade networks to provide iron to the agricultural populations in the regions around Munsa and Kibengo, and those who had remained in Bwera.

By the late thirteenth to fourteenth century, smelters at this site of Kyakaturi in the north of Mwenge were producing iron from a very rich iron ore containing considerable levels of phosphate, which would most likely have resulted in a tough yet workable metal. They were using refractory kaolinitic ceramics (which made very little contribution to the melt), in conjunction with a quartzitic flux to provide additional silica, which in turn enabled slag to form and the smelt to be successful. Their furnaces were half a metre in diameter and probably not particularly deep, enabling tight environmental control to be maintained over each smelt. From smelt to smelt, there was very little variation; this was evidently a tightly regulated system in operation.

Approximately twenty kilometres to the southwest, by the fourteenth century smelters were also operating furnaces at the site of Mirongo, perhaps attracted by the plentiful supply of high quality fuel available there in the form of the *Mirongo* tree – a tree that may have produced the lime-rich fuel that was particularly well suited to smelting, evidenced in the resulting slag blocks at the site. Although these smelters were using a very similar furnace to that at Kyakaturi, a different technological approach was being employed. The ore used in the smelts of Mirongo contained enough gangue that an additional quartz flux was not required. Furthermore, the technical ceramics in use were less refractory, and probably melted into the slag somewhat. Similarly to the furnace excavated at Munsa, which was also dated to approximately the fourteenth century, the shape of the furnace (and associated slag blocks) excavated at Mirongo (unlike that at Kyakaturi) suggests that only one tuyère may have been used to introduce air into the furnace.

---

of which are lost to the slag. The remaining 130 units of iron oxide convert to approximately 100 units of iron metal, per each 100 units of slag. The average weight of a complete slag block was 80kg. If 17 smelts are presumed (i.e. 1360kg slag), this gives an estimation of 1360kg iron produced; if 50 smelts are presumed, together they would have produced around 4000kg iron. This is an overestimation, but provides a rough guide to output.

These differences are not surprising: variations in local geology and geography between the areas surrounding Kyakaturi and Mirongo would have resulted in variations in the composition of raw materials available to the smelters – clay minerals, iron ores and charcoals – thereby eliciting differing responses to these materials, informed by different knowledge bases. Yet there was an even more dramatically different technology in operation at Mirongo, although not necessarily in operation at the same time. A second cluster of smelting activity at the site – undated – was found to be using an alternative technological approach, one that involved the separate addition of a manganese-rich material (that served, consciously or not, to increase the efficiency and output of the smelts per effort put in), as well as the use of banana plants and perhaps a differently shaped furnace. The presence of these two different approaches side-by-side (described in Chapter 5 as Group 1 and Group 2), is highly intriguing.

The common perception, as touched upon in Chapters 2 and 3, is that iron technologies would be fiercely guarded in order to protect knowledge of different smelting techniques and the access to wealth and power that this knowledge afforded. This might take the form of restricting the access of women to smelting sites (as women marry out into different family or clan lineages, potentially taking technological knowledge with them), or steeping the technology in rituals known only to the head smelter, thereby reducing the risk of 'defection' by skilled workers leaving to work elsewhere. It might well be assumed that during this period, when iron is seen to be one of the most important mechanisms for attracting followers and building a power base, that this would be truer than ever. Yet these hypotheses are based almost entirely on evidence from modern ethnographic examples, and have not yet been proven to have parallels in the distant past (although inferences have been made from the use of ritual 'medicinal' items found in or under ancient smelting furnaces). These concepts shall be returned to shortly.

The presence of two distinct iron production technologies in separate and defined clusters at the site of Mirongo might have been able to contribute to this debate, had it been possible to chronologically order these smelting remains. If it had been found that both areas of smelting activity were in operation within the same time frame, then a very interesting discussion would have arisen: namely, would that have demonstrated the coexistence of two discrete, rival smelting groups operating in close proximity but following different, closely protected, smelting 'recipes'? Alternative scenarios exist however. Perhaps access to the manganese-rich material was restricted or costly, and therefore unavailable to the Group 1 smelters. Or perhaps the smelters at Group 1 were producing a different (softer?) type of iron for a different set of consumers or for a different purpose than the smelters at Group 2[2]. Accounts seem to suggest that at least in the nineteenth and twentieth centuries, the Banyoro traded their high quality iron to Buganda, whilst keeping lower quality, softer iron for local consumption (Grant 1864; Roscoe 1923). Approached from a different angle, perhaps the presence of these two technologies instead demonstrates the uptake of a new smelting technique by the same group of smelters over time.

Although there is unfortunately very little concrete evidence available with which to address these interesting questions, there are several factors that make some of the above suggestions more or less likely. The lack of a "continuous lineage" of smelting technique (*cf.* Charlton 2009), plus the fact that the slag clusters are spatially distinct, indicates that this was not the result of a single group (even if a long-operating group over several generations) gradually developing a new technological process, or acquiring new technological knowledge. Furthermore, I believe that the use of banana plants within the Group 2 technologies (an approach not reflected in any other of the early smelting remains) seems an additional indication that this technology was potentially implemented sometime after Schoenbrun's 'banana revolution' had become firmly established in these westerly regions further removed from Lake Victoria. As it is, I strongly suggest that the Group 2 samples fit more closely with a pattern of production seen in later periods in the Mwenge area, and, in the absence of further data, I will discuss these smelting episodes in the next section.

[2] See also Charlton *et al.* 2010 for a discussion of ironworkers utilising two iron production recipes to produce two different types of iron.

By the first half of the fifteenth century, a period of higher rainfall had begun and agriculture was flourishing in the region north of the Katonga; major forest clearance was under way (Robertshaw and Taylor 2000). By this time we know that smelters were also in operation at the nearby site of Rugombe, less than ten kilometres from Mirongo, perhaps responding to the increased demand for iron tools for chopping trees and farming cereals. The persistence of memories of iron production at Rugombe (both from my informants, Robertshaw's and Lanning's) surely indicates that this was once a major centre of production. Here appears the first datable indication of a manganese-rich material being added to an iron ore, with the slag samples from the excavated furnace base at Rugombe registering a range of manganese-oxide levels from 3 to 7wt%. Although higher than that at the previous two sites (excepting what I am assuming to be the later Mirongo Group 2), this is significantly lower than the levels of manganese oxide in most of the later Mwenge sites, where manganese oxide levels could reach up to 12wt%. However, the slag blocks sampled from other areas of the site of Rugombe contained much less manganese oxide, between 1 and 3wt%. Could the evidence from this site indicate therefore a period of experimentation with a new technology? Again, unfortunately this will have to remain a tentative hypothesis that cannot be explored much further given the current level of data.

It is tempting to discuss these variations in smelting technology in terms of clans – at least as small, localised social units with a shared identity – moving through the landscape and responding to local stimuli for iron production (possibly the emergence of incipient elites at the centres of Munsa and Kibengo). If such a discussion is deemed appropriate (and I am aware that some may believe this not to be the case, *cf.* for example, Willis 1997) then the reconstructions of clan movement offered by Buchanan might be relevant to generate a broad view of social influences upon smelting, even if pinpointing an accurate association between specific clans and smelting style remains improbable. However, if nothing else, considering this time frame in this way offers the opportunity to bring to life the actors who gradually colonised this 'frontier zone' during this time.

It is in this period, from around the thirteenth century AD, that Buchanan sees the Basita and Basingo clans crossing the Victoria Nile far to the east of Mwenge. Certain parts of the Basita clan continue to move gradually to Mwenge through Singo, while others head initially northwest and arrive in Mwenge through Bugangaizi, where they eventually join the existing groups of Babopi and Bagabu clans that have been mentioned previously. Factions of the Basingo clan (also crossing the Nile around the thirteenth century) pass through the core areas of Buganda into Nkore, where they settle and acquire a new cattle-based totem. Later, these clans *also* arrived in Mwenge. If these reconstructions are to be believed, then it is possible that sections of different ironworking groups were arriving in Mwenge at various times throughout this period (presumably as well as smaller and/or unrecorded groups), bringing with them bodies of technological knowledge that had developed in response to different social, economic and environmental settings. This would have resulted in a melting pot of knowledge in Mwenge, allowing for vast combinations of potential approaches to smelting: the variations that we witness in the archaeological record.

Unfortunately, too little is known about the iron technologies of this area of the Great Lakes and the nature of clan affiliation and movement to infer specifics about the attribution of smelting style to family or clan group. Indeed, this line of enquiry may be counterproductive, distracting us from the more interesting questions of *how* these groups adapted ironworking knowledge to satisfy changing sets of requirements. What can be said though, is that discrete groups of smelters were operating competently and repeatedly using a method of smelting that they were comfortable and confident with, at all of the sites discussed here, with the exception perhaps of Rugombe.

In light of this, could the use of an additional manganiferous material, as seen initially (and tentatively) in the fifteenth century site of Rugombe, be a feature of a technology brought into Mwenge towards the end of this period, and integrated with existing iron technologies, such as those at Kyakaturi and Mirongo? This notion will be explored further, together with evidence regarding smelting in a public, open domain, with the introduction of the later sites of Kirongo and Kisamura in the following section. What can be emphasised in the interpretation of these remains, is the fact that local iron production was clearly well under way in this period, and ready to 'take off' at the time of the kingdoms: a dynamic shift towards new economic specialisations. The productive elements of the future Bunyoro kingdom are seen to be firmly in place by the fourteenth century, not only regarding iron production in Mwenge, but also salt production in Kibiro – production industries that continued well into the colonial era.

CONTEXTUALISING IRON PRODUCTION, 17TH – 20TH CENTURIES AD (1661-1954 cal. AD)

The period that we are next concerned with, that within which the remaining three furnace sites fall (and ostensibly Mirongo Group 2), corresponds neatly with the period of time attributed to the Bunyoro kingdom. This is a time that tends to be associated with both a greater demand for iron and a greater output, an industry encouraged by the Babito kings (Beattie 1960; Connah 1996). Iron was needed to fight ongoing battles in the region and replenish stocks of weaponry (Tosh 1970; Ingham 1975; Uzoigwe 1976), and therefore played a key role in trade, both local and long distance. When high-ranking visitors came to Bunyoro, the *omukama* gave hoes and salt as gifts to demonstrate the most valuable fruits of his kingdom (Roscoe 1923: 82).

Again, great change would have been experienced across western Uganda during this period, as incursions by incoming northern agro-pastoralists secured and consolidated power, and society became more stratified. For whatever reason, settlement patterns seem to have become more dispersed in this drier phase of the region's history, with regrowth of forest across many areas as well as expanding grasslands (Robertshaw and Taylor 2000; Taylor *et al.* 2000). As described in Chapter 2, the prevailing belief is that during this time power became more heavily focused on cattle. Although this may be true in terms of the ruling factions of the kingdom, on a local level agriculture, salt and iron are likely to have remained key commodities with which wealth and status were generated. As one of Buchanan's informants was earlier quoted to say, "in the long past there were not many cattle in Mwenge" (Buchanan 1974a: 102), a sentiment reinforced by Robertshaw's informants (1991b); what is broadly described as a 'shift' to pastoralism is not likely to indicate a wholesale rejection across the kingdom of local agriculture or mixed economies and all that goes with it, including demand for ironwork. Iron producing groups would have retained their status through their capability to keep local communities supplied with iron, as well as trading to neighbouring populations. The importance of iron production in these more recent periods is reflected in the positive attitude to ironworkers repeatedly expressed in accounts recorded at the time of colonial contact.

As mentioned earlier, it is not possible to estimate the number of iron production sites found during the 2007 survey that relate to this kingdom era (bearing in mind the current ceramic chronology that is available and the paucity of radiocarbon dates). It is also not possible to refine further at what point in the kingdom period the sites to be discussed here – Kisamura, Kirongo and Rukomero, as well as Mirongo Group 2 – were in operation. A weakness of the radiocarbon calibration curve at this time is its inability to generate more precise dates (*cf.* Killick 2004a; Guilderson *et al.* 2005), and as such it is impossible to suggest whether these sites were active during the earliest phases of the Nyoro kingdom or at the point of colonial contact, and also whether or not these sites were contemporary. However, it can probably be assumed that this was the age of the most intensive production of iron within western Uganda, and as such it might be expected (rightly or wrongly) that a greater degree of standardisation would be reflected in the remains from this LIA period. Indeed, this research was to find some dramatic consistencies in the dataset for this period, which may hint at a real drive to optimise iron production outputs and repeat successful processes. Yet variation was still present, expressed most clearly with the site of Rukomero. The conclusions from these sites will be discussed below.

Within this context, the sites of Kisamura and Kirongo showed strong similarities in technological approach to iron production, with both utilising a charge combining a manganese-rich fluxing agent as well as an iron ore, and both appearing to use furnaces fed by a single tuyère. The parallels between these reconstructed technologies and that described by Childs' informant are striking. Similarities also exist however, between the approach seen at Kisamura and Kirongo and the sites of Munsa and

Mirongo Group 1 (where a single tuyère was also used) and the later site of Rugombe (where a manganese-rich material was added to at least some of the smelts). As discussed previously, the chemical signature of the slag blocks from Mirongo Group 2 also closely matched this manganese-using technology, but there was not enough data by which to infer the number of tuyères used in these smelts.

Considering the similarities of the Kirongo-Kisamura smelting with the description of smelting by Childs' informant (i.e. the description of a second 'ore' and the prevalence of the use of a second manganese-rich material in these smelts, as well as the use of a single tuyère), it would be tempting to attribute this smelting style to the acquisition of elements of smelting technologies newly introduced into the area through later movements of clans coming from Nkore (*cf.* Chapter 2). However, with information from only one Bacwamba informant, linking this technological style to a clan (or even a group of clans) would be foolhardy. However, it might be possible to say that the occurrence of these features in the earlier sites indicates a transitional phase between one (probably of many) existing technology (single tuyère) and elements of an introduced technology (manganese-rich flux, *cf.* Table 8.1).

Site	Date (cal. AD)	Single tuyère?	Manganese-rich flux?
Munsa	1288 - 1425	✔	?
Kyakaturi	1290 - 1398	?	✖
Mirongo Group 1	1314 - 1430	✔	✖
Rugombe	1410 - 1450	Possibly	Some
Kirongo	1667 - 1949	✔	✔
Kisamura	1684 - 1929	✔	✔
Mirongo Group 2	-	?	✔
Rukomero	1661 - 1954	?	✖

Table 8.1 Summary of two elements of approach (single tuyère and manganese-rich flux) seen in iron smelting technologies across the research area

However, if iron production techniques are perceived to be strictly guarded, how could such transfer of technological information have occurred? Clues exist in the ethnohistorical data. Contrary to the suggestions of protection of knowledge, several of Buchanan's informants spoke of the *sharing* of technological knowledge between groups with knowledge of iron smelting and those without, and cooperation between different smelting and smithing groups. I believe that this is an important insight, and hints at an alternative scenario to the prevailing assumption of the protection of knowledge: one where information was sometimes shared, although not necessarily freely, and not necessarily all the time. This corresponds with ethnographic accounts regarding other technologies and regions of the world that demonstrate the intricacy of knowledge exchange, and the very personal qualities of trust and suspicion that shape interactions between craftspeople as individuals (e.g. Papousek 1989).

I happened upon information in the field that also made me consider the protection of iron production knowledge within Mwenge. Several of the informants I spoke to during survey emphasised the public nature of smelting: one informant stated that smelters (as well as smiths) generally located furnaces close to roads in order to advertise their trade and their wares; another that all and sundry could come and help with the bellowing, with the smelt publicised by the sound of the bellows echoing around neighbouring hills. An informant of Robertshaw's stated, "ore was taken to other areas or smelted close to communication routes (paths)" (Robertshaw 1991b). Schmidt and Childs (1996: 197-199) note the presence of an EIA occupation floor located only a matter of metres from contemporary furnace remains, although the nature of the occupation is unclear, adding to the suggestion that the location of iron production activity away from settlements may be more complex than is often presented (*cf.* Mapunda 2010: 224, 231-232).

Although these scenarios cannot be directly applied to the patterns of smelting practised in the fourteenth and fifteenth centuries, these statements provide a contrast to the popular notion of the location of iron smelting in places away from the general public, and away from chance encounters with (potentially smelt-endangering) women. Conversely, other informants during the 2007 survey *did* emphasise the secret nature of smelting, and this is something that MacLean encountered in Rakai district. Her informant chose not to reveal the medicines and ritual words used in smelting, neither to MacLean nor her interpreter, leading her to suggest, "the restricting of iron-working knowledge to a restricted group of iron-workers is still considered important, even seventy years after smelting was abandoned" (MacLean 1996: 29). Considering these contradictory accounts, it seems plausible (and sensible) to work on the assumption that both are valid: in the recent past some groups chose to guard their technologies closely, others to share their knowledge more freely. Perhaps this was also true in the more distant past, and presumably advantages accompanied both approaches.

As a brief aside, information gathered from the informants of both Robertshaw and myself encouraged me to consider the relationship of furnaces to roads and pathways; the site of Mirongo proved a particularly useful case in point. The furnace at Mirongo was located in the surface of a road that ran around the side of a hill. Was this furnace situated on a major pathway at the time of its operation? If the 'lip' of the furnace (*cf.* Figure 5.32) *does* indicate erosion from the blast zone, then the excavated furnace pit may well indicate the ground surface level at the time the furnace was dug. Considering the incline of the hill (into which the road cuts, *cf.* Figure 5.30), this prompted me to wonder how long this road had been in use. Frequently during survey, many of the furnace bases that are located are found in road surfaces (this survey; Connah 1996). This tends to be thought of as sampling bias, as roads are some of the few open ground surfaces with minimal cover that makes survey by sight possible (*cf.* Chapter 4; e.g. Humphris 2010). However, perhaps an alternative to consider is that in some cases these furnaces *were* originally located on the side of major roads, and the pathways we see today are remnants of much older pathways that have been etched into the landscape (*cf.* Roscoe 1915: 19). This might also add to the suggestion of a more public presence of smelting than is usually assumed (*cf.* Iles, forthcoming). However, this does not preclude the possibility that smelts and smelters were separated from passers by with fencing, as witnessed in Karagwe (A. Reid pers. comm. 2010), and Childs mentions that some (though not all) smelters were said to screen off their smelting areas using a plant called *orusororo*, whose name means "to separate" (Childs 1999: 32).

Returning to the use of a manganese-rich material, it is significant that this documented use of two 'ores' – one mined, one collected from the surface – exists in several other accounts of smelting in the region (*cf.* Chapter 7), in areas where elevated manganese levels have not yet been detected (e.g. Hoima, Buganda[3]). Perhaps it is possible that this technological trait was communicated from group to group through a description of the appearance of *entabo* (or equivalent). Even direct observation could be misleading, resulting in the collection of similar looking – but geologically different – materials. Whether this resulted in the collection of a manganiferous laterite, non-manganiferous laterite or a magnetitic gravel (potentially outwardly similar looking materials) would depend on the local availability of materials surrounding the new smelting location. As a result, some of these smelting groups would acquire the benefits of using a manganese-enriched material in their smelts, whereas others would not. Again, this is just conjecture, as there may be no (or an alternative) link between these technologies.

However, exploring this idea further, the differential availability of manganiferous materials across the landscape may have resulted in different outcomes for different smelting groups, who see themselves as using a similar technique. The reputation that Banyoro smelters enjoyed across the region in at least the latter half of the second millennium was for the production of hard, strong, high quality iron; this may well have been due to the utilisation of such a *manganiferous* flux (*cf.* Chapter 7). An awareness of the need to mix two 'ores' to make the resultant iron hard (e.g. Robertshaw's informant Damazo; Buchanan's informant Winyi) allowed smelters to choose as and when they wanted, or needed, to make this harder iron. If neighbouring groups were unknowingly using a second 'ore' with a different chemical composition (e.g. magnetite), then it may not have resulted in the superior metal that Nyoro smelters manufactured.

Finally, the site of Rukomero offers an important reminder that alternative ways of smelting continued alongside manganese-rich, single tuyère methodologies; here,

[3] Archaeometallurgical analysis of smelting remains from the Buganda kingdom to the east of Mwenge contained markedly less manganese oxide. The analysed slag blocks from four smelting sites (Kinanisi, Masaka, Masaaba and Birinzi) each contained less than 1wt% manganese oxide (with the exception of one slag block from Masaaba, which contained 2wt% manganese oxide) (Humphris 2004, 2009). This is a region that also has a tradition of the use of two ores: one male, one female (Roscoe 1911), although Roscoe's smelters were not from the two areas of Buganda that were examined in this instance.

neither of these technological approaches appear to have been used. Further removed geographically from the central Mwenge sites, smelters at Rukomero (as at Mirongo Group 1) may not have had access to *entabo* with which to supplement their smelts (although markets at Kigugu presumably would have been accessible to them[4]), may have chosen to smelt without *entabo*, perhaps to supply a different market (*cf.* also Charlton *et al.* 2010), or through personal preference, or may have not known about the technology. Whatever the reason, this site is an important reminder of the risks of over-generalisation from a single excavated site or a single ethnoarchaeological account. Even in the iron-hungry kingdom era, iron production in western Uganda was neither centralised nor standardised, and localised variation continued to occur.

REVIEW AND SUMMARY

The data presented within this thesis has demonstrated that no singular technological approach can define Mwenge iron production during any period covered by this research, let alone across the wider region of western Uganda. Variations in technological approach were common, although techniques could span several smelting groups. These variations may have grown in response to differential access to resources, different knowledge bases, or in order to fulfil different outcomes – or, of course, a combination of all three.

A significant discovery has been the utilisation of (at least) two 'ores' at several of the sites, one of which was manganese enriched. This bears intriguing correlations with a range of ethnographic information gathered from the same region that document the use of 'male' and 'female' ores. The use of this manganese-rich material would have had noticeable impacts on the performance and outcomes of the smelts in which it was used. Furthermore, a macroscopic examination of the remains (regarding furnace and slag shape) has been able to suggest that only one tuyère was used per smelt at

[4] Markets seem to have existed for raw materials as well as for bloomery iron and finished products, at least during later periods. As well as the market for *entabo* that Childs mentions, (which may also be referring to Kisinga, although this is not specified; *cf.* Chapter 7), Damazo Mayonbo said that smelters (often from Murongo in Kihura sub-county, approximately 20km to the east of Kigugu, along the main road to Matiri) came and bought ore at Kisinga (Robertshaw 1991b).

several of the smelting sites, which again correlates with Childs' ethnoarchaeological account of smelting in Mwenge as well as the archaeological evidence from Munsa.

The density of ironworking sites detected during survey (although it is not currently possible to distinguish whether these are attributable to either the later or earlier periods of this study), indicates a very high volume of production in the region, with accumulations of iron slag to be found almost at every turn around the southwest part of the survey zone in particular. These sites occurred in a range of environments and locations, and were small to moderate in size (*cf.* Chapter 4). Mining sites were also frequently encountered during survey; this certainly is an area rich in iron ore. Such a high intensity of iron production remains at a large number of discrete sites means that there must have been a great number of smelting groups plying their trade here from the time that ironworking became established in the region. Evidence generated through this research suggests that this had occurred in Mwenge by or before the fourteenth century, and is likely to have expanded in step with population growth in this part of western Uganda through the second millennium AD and in conjunction with several other activities (e.g. salt production). From the research so far, there appears to be no marked difference between iron production of earlier and later periods, which might suggest that there existed relatively large-scale production from the fourteenth century onwards. These technologies must, however, have developed earlier – the early smelting technologies that we have encountered here are well established and well executed – but how much earlier is yet to be determined.

Understanding how these different groups interacted and were organised is a key aim, and the most difficult to fathom. One aspect that this research has begun to touch upon is the relationship between clan and family group and smelting style. How far this line of enquiry can go in order to understand the relationships between different groups of smelters only future research will tell. Similar investigations of small-scale movements of people across the regional landscape might eventually also prove to be useful in understanding wider patterns of smelting style. Whilst excavating smelting remains at the village of Kiwesi in the Kooki survey area (see Appendix A), the current inhabitants told us that their ancestors came from Bunyoro. Might this mean that at least some aspects of the smelting style practiced at Kiwesi bore some relationship to a body of ironworking knowledge that was acquired in Bunyoro? Might the domed furnaces described by Roscoe in Hoima and Nkore (1915, 1923) bear some stylistic relationship to the domed furnaces described by MacLean's informant in Rakai (1996) that hints at a *knowledge* relationship between these regions?

These connections are difficult to untangle: what one technology might introduce into an area might be readapted and changed until it is quickly unrecognisable. Yet certain features of technologies may be seen to persist, even regionally, and this could provide insights not only of how well-respected craft practitioners moved across the landscape, but also of which elements of a technology are deemed necessary or important to retain, and which are discarded or adapted. We know that technology responds not only to changes in resource availability, environmental constraints, socio-economic circumstances and market forces, but that it is also sensitive to the inspiration, innovations and attitudes to change of its individual practitioners, as well the entrenched dogmas of producers and consumers.

The variations that exist within iron production technologies have recently been much emphasised, both within sub-Saharan Africa and across the world (e.g. Childs 1991; Killick 1991; Schmidt 2001; Veldhuijzen 2005; Paynter 2006; Rehren *et al.* 2007; Iles and Martinón-Torres 2009; Humphris 2010 and many others). Yet research that has taken up the challenge to explain this variation has been limited:

> "Diachronic processes underpinning the transfer of technical knowledge and the evolution of ironmaking technology have, out of necessity, been ignored or assumed for all but the most recent historically documented examples"
> (Charlton *et al.* 2010: 353)

It is hoped that this research has not only highlighted the variation that exists within the iron producing communities of western Uganda and the outcomes resulting from it, but has also gone on to introduce some initial suggestions as to the mechanisms behind this variation. A community's relationship with technology is both social and intimate; bloomery ironworkers are craftspeople, not cogs in a faceless machine. In today's highly industrialised world, we can easily forget the personal relationship that exists between a craftsman and his craft: the development of personal knowledge and experience throughout a lifetime ultimately defines the operation and conceptualisation of each and every smelt.

PART TWO: ARCHAEOLOGICAL IMPLICATIONS

In order to facilitate the incorporation of this work into the wider body of existing archaeological and archaeometallurgical research, it is important that the successes of this research, as well as its limitations, are explicitly expressed. Through an examination of these qualities, possible suggestions as to future research directions are also highlighted, and are presented below.

CONTRIBUTION TO THE DISCIPLINE

This work has comprised the first archaeometallurgical examination of iron production in western Uganda, and the data presented within the preceding chapters has proved it to have been a fruitful undertaking. In a region where very little archaeological work had previously been undertaken, detailed survey and excavation at a number of sites in Mwenge has demonstrated the effectiveness of archaeological endeavour here. By combining intensive survey, excavation and archaeometric analysis with ethnoarchaeological, ethnohistorical and oral historical data, one of the most important crafts within precolonial western Uganda has been illuminated.

The iron technologies employed at six smelting sites in Mwenge have been partly reconstructed, encompassing descriptions of the technical methodologies that were followed at each site, as well as interpretations of some of the social aspects that would have surrounded such technologies. Small-scale technological variation has been examined in detail, both within individual iron smelting sites, and between sites. A developed understanding of these patterns of variation holds the key to appreciating the complexity of iron production organisation and the pressures acting upon individuals and groups of smelters as they made technical choices.

Through the study of a range of sites within a small area, spanning from what are currently some of the earliest examples of smelting in western Uganda to furnaces in operation during the kingdom-era, a story of iron production within a range of political and social environments has been constructed. The position of western Uganda within the EIA however, remains uncertain. In contrast to other areas of the Great Lakes, this research appears to confirm suggestions that the region was indeed a 'frontier' zone during this time, and as such the 'coming of the age of iron' in western Uganda may not fit with the common chronological pattern seen in the wider region. This reminds us that the Great Lakes is not a homogeneous cultural entity, and that the internal dynamics of such a region should not be overlooked. Instead, the organisation of society and the organisation of iron production should be examined on a cross-cultural basis.

This research has also been able to challenge some prevailing attitudes towards the organisation of iron production in the past, in the Great Lakes and perhaps in sub-Saharan Africa as a whole. This has centred primarily around the protection and transfer of technical knowledge, but also considers the role of women in smelting events (*cf.* Iles, forthcoming). In this paper, I argue that research biases may have served to hide or obscure some of the variation that may have existed in the social and ritual aspects of smelting. I suggest that aside from early research, that tended to focus on the more 'exotic' examples, even modern survey methodologies have a tendency to reinforce existing paradigms of technological practice. Researchers tend to go through the "usual channels" to locate informants, being passed from government official to local official to local informant, a process which restricts the informant base greatly, to what might be called an 'old boys network'. As an example, the informants that Childs and Robertshaw got much of their information from in the 1990s (Damazo and Ndunga) were the same informants who were interviewed by Trowell and Wachsmann in 1941 for their book *Tribal Crafts of Uganda* (1953). It was only through undertaking a different form of 'untargeted' survey during this research that alternative (and sometimes conflicting) voices were heard. It is by looking at iron smelting on such a small scale, both archaeologically and ethnoarchaeologically, that a secure approach to large-scale questions can be assured. As Schmidt (1998: 141) reminds us:

> "In archaeology … we have learned that it is the anomaly, the piece of evidence that does not fit the model or analog, that begs to be explained and therefore holds the key to understanding change and reveals deeper systems of meaning."

Although no definitive conclusions have been made about the organisation of iron production in western Uganda, this research has reinforced the importance of keeping an open mind and of challenging prevailing views. It seems that to a certain extent, studies of African iron smelting moved away from an emphasis on technological homogeneity only to replace it with an emphasis on shared social and symbolic themes: the "underlying symbolic armatures that link many iron technologies across sub-Sahara Africa" (Schmidt and Mapunda 1997: 75). Whilst variation within technique and style is widely accepted, more should be done to scrutinise the possible range of personal responses to the changeable social and economic contexts within which technology is embedded (*cf.* Schmidt 2001; Killick 2004b; Chirikure 2007). It is through a more complete understanding of these nuances of approach that a realistic and revealing picture can be built of how past smelters operated and interacted within the confines of their political, social and environmental settings.

I would go further to state that this research has highlighted one of the most significant dangers of using ethnohistoric or ethnographic information. In each reconstruction (or interview series), an ethnographic account focuses on only one master smelter's method for iron production. This research suggests that what is likely to be a high level of local technological variation is unable to be expressed within just one reconstruction. Unlike anthropologists or sociologists, archaeologists tend to spend a very restricted time in the field with their informants, and should be aware of the limitations that this places on the depth and range of their gathered data.

Furthermore, considering these iron technologies within a framework of fluid and fluctuating population demographics has instigated a new arena for the consideration of the movement of people and the spread of elements of technological knowledge. Of course, at this early stage of research into the iron production of western Uganda there is a need to remain cautious about interpretations of these data. Dating in particular could hold the key to more robust analysis of patterns in the technologies. Yet through this work, the scene has been set for future research to develop methodologies that can test and examine some of the proposed pathways through which knowledge of these technologies were acquired, adapted and optimised to suit new local needs and increasing demand.

LIMITATIONS OF THE RESEARCH AND FUTURE POSSIBILITIES

By beginning to shed light on these local industries, many more questions have been raised than answered. The incomplete preservation and recovery of archaeological remains, and the imperfect nature of archaeological interpretation, means that there are always aspects of past human behaviour that go unnoticed or misunderstood. Precolonial iron smelting in western Uganda is no exception.

Due to the available archaeological remains, as described in Chapters 5 and 6, there are many pertinent aspects of iron smelting that have not been explored. Most particularly, as highlighted by Connah (1996: 4), by not being able to relate smelting activity to habitation sites or other remains, due to poor archaeological preservation of such materials and the intensive use of land in recent years, little can be firmly concluded about the relationship between the smelters and the wider society that they operated within. This is an unfortunate gap in the data, and one that is not going to improve dramatically. A primary technological link between the smelting process and the community – i.e. smithing and the production of iron artefacts for use – is an aspect of the full *chaîne opératoire* of iron production for which archaeological remains are also unfortunately lacking at present.

Greater knowledge of the social and technological landscapes of western Uganda prior to the fourteenth century would also be instrumental in understanding the dynamics of early iron production across the region. It is possible that the survey methodology employed – whilst useful in locating a large number of sites and interacting with a wide range of local people – may not have been as well equipped to locate earlier sites, which might tend to be characterised by fewer remains and be less prominent in local peoples' memories of the region. Further detailed survey employing a range of methodologies, to locate sites as well as to assess site location and scale of production would be most informative in the future, as would survey undertaken to understand the raw materials available in the local area.

The ethnohistorical evidence, although very useful in trying to fill these gaps in the archaeological data, cannot represent the whole variety of smelting practices undertaken across western Uganda, nor can they necessarily be telescoped directly onto the past (*cf.* Chapter 3). Interviews and reconstructions with individuals or select groups of (past) smelters cannot be taken to convey the range of technologies of a given region, no matter how small. However, they have indicated different avenues of exploration that have yet to be followed (such as the proximity of smelting activity to roads, pathways or even crossroads, the sharing of knowledge, movements of smelting groups and so on) and which may prove to have real potential for future archaeological approaches to iron production in this region.

A greater body of research is the only way to address many of the interesting social questions raised by this study. A larger number and wider scope of oral historical and ethnoarchaeological studies with a focus on iron production and identity, in conjunction with an expansion of the archaeometallurgical data, would allow for any potential connections between style and clan to be corroborated or refuted. Unfortunately, as time passes the informants available to recount detailed descriptions of smelting processes are disappearing.

The inability to reliably and accurately date sites and smelting episodes has been one of the biggest barriers to this research. Given opportunities to directly date smelting episodes through direct analysis of slag blocks, or through the more accurate and precise dating of furnace remains using TL or OSL, a more informative picture might have been drawn of technological change over time (Gautier 2001; Haustein *et al.* 2003). However, these methods are in their relative infancy and are in the process of being refined, they still rely on imprecise calibration, are very expensive to implement, and can potentially fail (*cf.* Humphris 2010). With only a handful of radiocarbon dates, which spanned large age ranges (*cf.* Guildeson *et al.* 2005), this research was necessarily restricted in its chronological outlook.

From a metallurgical point of view, more work is needed to understand the effects of smelting with a manganiferous iron ore in a bloomery furnace, both regarding the operational parameters of such a smelt, and what effect there might be on the resulting iron metal. Does manganese transfer to the metal and impart tangible mechanical effects within a bloomery environment? The high manganese oxide content of many of the slag blocks from this region is also of importance. The analysis of slag inclusions in iron artefacts may provide the opportunity to consider the provenance of iron artefacts from across the Great Lakes (*cf.* Paynter 2006; Blakelock *et al.* 2009; Desaulty *et al.* 2009), potentially pinpointing how far Mwenge iron, with its superior reputation, had been traded.

Nevertheless, despite these drawbacks, this research has highlighted a technology that shaped the lives of countless Banyamwenge iron smelters, and those that they traded to, over at least a six hundred year period. Their hard labour remains preserved in the slag blocks that are scattered throughout the landscape; the fruits of that labour remain in the communities that continue to live in this iron rich region, as after all, 'a hoe bought a wife'.

Alcock, C. 1976. *Principles of Pyrometallurgy*. Academic Press: London

Allen, R. 1979. International Competition in Iron and Steel, 1850-1913. *The Journal of Economic History* 39: 911-937

Alpern, S. 2005. Did They or Didn't They Invent It? Iron in sub-Saharan Africa. *History in Africa* 32: 41-94

Andah, B. 1995a. European Encumbrances to the Development of Relevant Theory in African Archaeology. In: P. Ucko (ed.) *Theory in Archaeology: a world perspective.* 96-109. London: Routledge

Andah, B. 1995b. Studying African Societies in Cultural Context. In: P. Schmidt and T. Patterson (eds.) *Making Alternative Histories: the practice of archaeology and history in non-western settings.* 149-181. Santa Fe: School of American Research Press

Arnold, B. 1999. The Contested Past. *Anthropology Today* 15: 1-4

Arnold, D. 2000. Does the Standardization of Ceramic Pastes Really Mean Specialization? *Journal of Archaeological Method and Theory* 7: 333-375

Ascher, R. 1961. Analogy in Archaeological Interpretation. *Southwestern Journal of Anthropology* 17: 317-325

Ashley, C. 2005. *Ceramic Variability and Change: A Perspective from Great Lakes Africa.* Unpublished PhD thesis. London: UCL

Ashley, C. 2010. Towards a Socialised Archaeology of Ceramics in Great Lakes Africa. *African Archaeological Review* 27: 135-163

Ashley, C. and Reid, D. A. M. 2008. A reconsideration of the figures from Luzira. *Azania* 43: 95-123

Austen, R. and Headrick, D. 1983. The Role of Technology in the African Past. *African Studies Review* 26: 164-181

Babiiha, J. 1958. The Bayaga Clan of Western Uganda. *Uganda Journal* 22: 123-130

Bachmann, H.-G. 1982. *The Identification of Slags from Archaeological Sites.* London: Institute of Archaeology

Badenoch, W. 2004. *An Investigation into the Kako Mine Shafts and the Possible Uses of Kaolin Within the Buganda Kingdom of Uganda.* Unpublished BA dissertation. London: UCL

Barifaijo, E. 2000. *Geology in Uganda.* Kampala: Makerere University

Barndon, R. 1996. Fipa Ironworking and its Technological Style. In: P. R. Schmidt (ed.) *The Culture and Technology of African Iron Production.* 58-73. Gainesville: University of Florida Press

Barndon, R. 2004. *An Ethnoarchaeological Study of Iron Smelting Practices Among the Pangwa and Fipa in Tanzania.* Oxford: Archaeopress

Barrett, J. 2000. A Thesis on Agency. In: M.-A. Dobres and J. Robb (eds.) *Agency in Archaeology*. 61-68. London: Routledge

Barrett, J. 2001. Agency, the duality of structure, and the problem of the archaeological record. In: I. Hodder (ed.) *Archaeological Theory Today*. 141–164. Cambridge: Polity Press

Beattie, J. 1960. *Bunyoro: an African Kingdom.* New York: Holt, Rinehart and Winston

Beattie, J. 1968. Aspects of Nyoro Symbolism. *Africa: Journal of the International African Institute* 38: 413-442

Beattie, J. 1971. *The Nyoro State.* Oxford: Oxford University Press

Beidelman, T. 1970. Myth, legend and history: a Kaguru traditional text. *Anthropos* 65: 89-91

Bent, J. 1902. *The ruined cities of Mashonaland: being a record of excavation and exploration in 1891.* London: Longmans

Bentley R., Maschner, H. and Chippindale, C. 2008. (eds.) *Handbook of Archaeological Theories*. Plymouth: AltaMira Press

Berger, I. 1980. Deities, dynasties and oral tradition: the history and legend of the Abacwezi. In: J. Miller (ed.) *The African Past Speaks: essays on oral tradition and history.* 61-81. Hamden: Dawson Archon

Bikunya, P. 1927. *Ky'Abakama ba Bunyoro.* London: Sheldon Press

Blakelock, E., Martinón-Torres, M., Veldhuijzen, X. and Young T. 2009. Slag inclusions in iron objects and the quest for provenance: an experiment and a case study. *Journal of Archaeological Science* 36: 1745-1757

Borchert, H. 1970. On the ore-deposition and geochemistry of manganese. *Mineralium Deposita* 5: 300-314

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51: 337-360

Brown, J. 1995. *Traditional Metal Working in Kenya.* Oxford: Oxbow

Buchanan, C. 1974a *The Kitara complex: the historical tradition of Western Uganda to the 16th century*. Unpublished PhD thesis. Bloomington: Indiana University

Buchanan, C. 1974b. Of Kings and Traditions: the case of Bunyoro-Kitara. *The International Journal of African Historical Studies* 7: 516-527

Buchanan, C. 1978. Perceptions of ethnic interaction in the east African interior: the Kitara complex. *The International Journal of African Historical Studies* 11: 410-428

Buchanan, C. 1979. Courts, clans and chronology in the Kitara complex In: J. Webster (ed.) *Chronology, Migration and Drought in Interlacustrine Africa.* 87-124. London: Longman Press

Buchwald, V. 2003. Bloomery iron, osmund iron, fined iron and puddle iron. In: L. Nørbach (ed.) *Prehistoric and medieval direct iron smelting in Scandinavia and Europe: aspects of technology and society.* 171-176. Aarhus: Aarhus University Press

Caton-Thompson, G. 1929. Zimbabwe: based on the British Association report. *Antiquity*: 424-433

Cech, B. 2008. The bloomery furnaces and smithing hearths. In: B. Cech (ed.) *The Production of Ferrum Noricum at the Hüttenberger Erzberg: the results of interdisciplinary research at Semlach/Eisner between 2003-2005.* 71-95. Vienna: OGA

Célis, G. 1987. *Introduction a la Metallurgie Traditionelle au Rwanda: techniques et croyances.* Rwanda: Institute National de Recherche Scientifique

Célis, G. and Nzikobanyanka, E. 1976. *La Metallurgie traditionelle au Burundi (techniques et croyances)*. Tervuren: Musee Royal de l'Afrique Centrale

Chakrabarti, D. 1976. The beginning of iron in India. *Antiquity* 50: 114-124

Charlton, M. 2007. *Iron Working in Northwest Wales: an Evolutionary Analysis.* Unpublished PhD thesis. London: UCL

Charlton, M. 2009. Identifying iron production lineages: a case study in northwest Wales. In: S. Shennan (ed.) *Pattern and Process in Cultural Evolution.* 133–144. Berkeley: University of California Press

Charlton, M., Crew, P., Rehren, Th., Shennan, S. 2010. Explaining the evolution of ironmaking recipes – an example from northwest Wales. *Journal of Anthropological Archaeology* 29: 352-367

Charsley, S. 1970. Mobility and village composition in Bunyoro. *Uganda Journal* 34: 15-27

Childe, V. G. 1930. *The Bronze Age.* New York: Biblo and Tannen

Childe, V. G. 1940. *Prehistoric Communities of the British Isles.* London: Chambers

Childe, V. G. 1956. The Bronze Age. *Past and Present* 12: 2-15

Childs, S. T. 1988. Clay resource specialization in Tanzania: implications for cultural process. In: C. Kolb (ed.) *Ceramic Ecology Revisited 1987: the technology and socioeconomics of pottery*. 2-31. Oxford: BAR

Childs, S. T. 1989. Clays to Artifacts: resource selection in African Early Iron Age iron-making technologies. In: G. Bronitsky (ed.) *Pottery Technology: ideas and approaches.* 139-164. London: Westview Press

Childs, S. T. 1991. Style, technology and iron-smelting furnaces in Bantu-speaking Africa. *Journal of Anthropological Archaeology* 10: 332-59

Childs, S. T. 1994. Society, culture and technology in Africa: an introduction. In: S. T. Childs (ed.) *Society, Culture and Technology in Africa.* 6-14. Pennsylvania: MASCA

Childs, S. T. 1996. Continuities and adaptations of iron working in Tanzania: evidence from the laboratory. In: P. R. Schmidt (ed.) *The Culture and Technology of African Iron Production.* 277-320. Gainesville: University Press of Florida

Childs, S. T. 1998a. 'Find the ekijunjumira': iron mine discovery, ownership and power among the Toro of Uganda. In: A. Knapp, V. Pigott and E. Herbert (eds.) *Social Approaches to an Industrial Past: the archaeology and anthropology of mining.* 123-137. London: Routledge

Childs, S. T. 1998b. Social identity and craft specialization among Toro iron workers in Western Uganda. *Archaeological Papers of the American Anthropological Association* 8: 109-121

Childs, S. T. 1999. 'After all, a hoe bought a wife': the social dimensions of ironworking among the Toro of East Africa. In: M. Dobres and C. Hoffman (eds.) *The Social Dynamics of Technology: practice, politics and world views.* 23-45. London: Smithsonian Institution Press

Childs, S. T. 2000. Traditional iron working: a narrated ethnoarchaeological example. In: M. Bisson, S. T. Childs, P. de Barros and A. Holl (eds.) *Ancient African Metallurgy: the socio-cultural context.* 199-253. Walnut Creek: Altamira

Childs, S. T. and Herbert, E. 2005. Metallurgy and its Consequences. In: A. Stahl (ed.) *African Archaeology: A Critical Introduction.* 276-301. London: Blackwell.

Childs, S. T. and Killick, D. 1993. Indigenous African metallurgy: nature and culture. *Annual Review of Anthropology* 22: 317-37

Chirikure, S. 2002. *A Metallurgical Investigation of Iron Processing Remains from Nyanga, Northeastern Zimbabwe.* Unpublished MA dissertation. London: UCL

Chirikure, S. 2005. *Iron Production in Iron Age Zimbabwe: Stagnation or Innovation?* Unpublished PhD thesis. London: UCL

Chirikure, S. 2007. Metals in Society: Iron Production and its Position in Iron Age Communities of Southern Africa. *Journal of Social Archaeology* 7: 72-100

Chirikure, S. and Rehren, Th. 2004. Ores, Slags and Furnaces: Aspects of Iron Working in the Nyanga Complex. *African Archaeological Review* 21: 135-152

Chirikure, S. and Rehren, Th. 2006. Iron Production in Pre-colonial Zimbabwe: Evidence for Diachronic Change at Swart Village and Baranda. *Journal of African Archaeology* 4: 37-54

Chrétien, J.-P. 1985. L'empire des Bacwezi la construction d'un imaginaire Géopolitique. *Annales. Histoire, Sciences Sociales* 6: 1335-1377

Chrétien, J.-P. 2003. *The Great Lakes of Africa: a thousand years of history*. New York: Urzone

Chrétien, J.-P. 2006. *The Recurring Great Lakes Crisis: identity, violence and power.* London: Hurst

Clark, J. 1995. Craft specialization as an archaeological category. *Research in Economic Anthropology* 16: 267-294

Cline, W. 1937. *Mining and Metallurgy in Negro Africa.* Wisconsin: George Banta

Cochrane, E. 2001. Style, Function, and Systematic Empiricism: the conflation of process and pattern. In: T. Hurt and G. Rakita (eds.) *Style and Function: Conceptual Issues in Evolutionary Archaeology*. 183-202. Westport: Bergin and Garvey

Coghlan, H. 1977. *Notes on Prehistoric and Early Iron in the Old World.* Oxford: Pitt Rivers Museum, Occasional Papers on Technology 8

Cole, S. 1954. *The Prehistory of East Africa*. London: Penguin

Collett, D. 1993. Metaphors and representations associated with precolonial iron-smelting in eastern and southern Africa. In: T. Shaw, P. Sinclair, B. Andah and A. Okpoko (eds.) *The Archaeology of Africa: food, metals and towns*. 499-511. London: Routledge

Connah, G. 1990. Archaeology in Western Uganda. *Nyame Akuma* 34: 38-45

Connah, G. 1991. The salt of Bunyoro: seeking the origins of an African kingdom *Antiquity* 65: 479-94

Connah, G. 1995. Paper presented at the 10th Pan-African Congress of Prehistory, Harare 1995

Connah, G. 1996. *Kibiro: the salt of Bunyoro, past and present.* London: BIEA

Connah, G. 2001. *African Civilizations: an archaeological perspective*. Cambridge: Cambridge University Press

Connah, G., Kamuhangire, E. and Piper, A. 1990. Salt-production at Kibiro. *Azania* 25: 27-39

Costin, C. 1991. Craft specialization: issues in defining, documenting and explaining the organisation of production. *Archaeological Method and Theory* 3: 1-56

Costin, C. 2000. The use of ethnoarchaeology for the archaeological study of ceramic production. *Journal of Archaeological Method and Theory* 7: 377-403

Costin, C. 2005. Craft Production. In: H. Maschner (ed.) *Handbook of Archaeological Methods*. 1034-1107.Walnut Creek: AltaMira

Costin, C. and Hagstrum, M. 1995. Standardization, labor investment, skill and the organization of ceramic production in Late Prehispanic Highland Peru. *American Antiquity* 60: 619-39

Craddock, P., Freestone, I., Middleton, A. and Van Grunderbeek M.-C. 2007. The scientific study of some Early Iron Age iron smelting debris from Rwanda and Burundi, East Africa. *Historical Metallurgy* 41: 1-14

Crawhall, T. 1933. Iron working in the Sudan. *Man* 33: 41-43

Crazzolara, J. 1937. The Lwoo People. *Uganda Journal* 5: 1-21

Crew, P. 2000. The influence of clay and charcoal ash on bloomery slags. In: C. Cucini-Tizzoni and M. Tizzoni (eds.) *Il Ferro Nelle Alpi.* 38-48. Proceedings of an International Conference at Bienno, October 1998

Crew, P. and Charlton, M. 2007. The anatomy of a furnace and some of its ramifications. In: S. La Niece, D. Hook and P. Craddock (eds.) *Metals and Mines: Studies in Archaeometallurgy*. 219-225. London: Archetype Publications

Crowley, T. and Bowern, C. 2009. *An Introduction to Historical Linguistics.* Oxford: Oxford University Press

Dale, D. and Ashley, C. 2010. Holocene hunter-fisher-gatherer communities: new perspectives on Kansyore using communities of Western Kenya. *Azania: archaeological research in Africa* 45: 24-48

Dale, D., Marshall, F. and Pilgram, T. 2004. Delayed-return hunter-gatherers in Africa? Historic perspectives from the Okiek and archaeological perspectives from the Kansyore. In: G. Crothers (ed.) *Hunters and Gatherers in Theory and Archaeology*. 340-375. Carbondale: Southern Illinois University

David, N. 1992. Integrating Ethnoarchaeology: a subtle realist perspective. *Journal of Anthropological Research* 11: 330-359

David, N. 2001. Lost in the Third Hermeneutic? Theory and methodology, objects and representations in the ethnoarchaeology of African metallurgy. *Mediterranean Archaeology* 14: 49-72

David, N. and Kramer, D. 2001. *Ethnoarchaeology in Action.* Cambridge: Cambridge University Press

David, N., Heinmann, R., Killick, D. and Wayman, M. 1989. Between bloomery and blast furnace: Mafa iron smelting technology in North Cameroon. *African Archaeological Review* 7: 183-208

Davis, M. 1952. *A Lunyoro-Lunyankole-English and English-Lunyoro-Lunyankole Dictionary.* London: Macmillan and Co

Davison, P. 2001. Typecast: Representations of the Bushmen at the South African Museum. *Public Archaeology* 1: 3-20

Davison, P. 2005. Museums and the Re-shaping of Memory. In: G. Corsane (ed.) *Heritage, Museums and Galleries: an introductory reader.* 184-194. Oxford: Routledge

Dawkins, R. 2006. *The God Delusion.* London: Bantam Press

de Barros, P. 2000. Iron Metallurgy: sociocultural context. In: M. Bisson, S. T. Childs, P. de Barros and A. Holl (eds.) *Ancient African Metallurgy: the socio-cultural context.* 147-98. Walnut Creek: Altamira

de Maret, P. 1985. The Smith's myth and the origins of leadership in central Africa. In: R. Haaland and P. Shinnie (eds.) *African Iron Working: Ancient and Traditional.* 73-87. Oslo: Norwegian University Press

de Maret, P. 1990. Phases and facies in the archaeology of central Africa. In: P. Robertshaw (ed.) *The History of African Archaeology.* 109-134. London: James Currey

de Maret, P. 1994/1995. Pits, pots and the far-west streams. *Azania* 29-30: 318-323

de Maret, P. 1999. The power of symbols and the symbols of power through time: probing the Luba past. In: S. McIntosh (ed.) *Beyond Chiefdoms: Rethinking Complexity in Africa.* 124-38. Cambridge: Cambridge University Press

de Maret, P. 2002. Urban origins in central Africa: the case of Kongo. In: *The Development of Urbanism from a Global Perspective.* From the 'Urban Origins in Eastern Africa' conference, Mombasa 1993. Uppsala: Uppsala Universiteit [accessed online at http://infoglue.uu.se/Forskning/Publikationer/Digital/Development_of_Urbanism/ on 15 Nov 2010]

Deane, E. 2007. *Visualising History: The Mackie Ethnological Expedition (1919-1920) to Eastern Africa as seen through the photographs of the Reverend John Roscoe.* Unpublished MA dissertation. Norwich: University of East Anglia

Desaulty, A.-M., Dillmann, P., L'Héritier, M., Mariet, C., Gratuze, B., Joron, J.-L. and Fluzin, P. 2009. Does it come from the Pays de Bray? Examination of an origin hypothesis for the ferrous reinforcements used in French medieval churches using major and trace element analyses. *Journal of Archaeological Science* 36: 2445-2462

Desmedt, C. 1991. Poteries Anciennes Décorées à la Roulette Dans la Région des Grands Lacs. *The African Archaeological Review* 9: 161-196

Dillmann, P., Balasubramaniam, R. and Beranger, G. 2002. Characterization of protective rust on ancient Indian iron using microprobe analyses. *Journal of Corrosion Science* 44: 2231-2242

Dissanayake, C. 1980. Mineralogy and chemical composition of some laterites of Sri Lanka. *Geoderma* 23: 147-155

Dobres, M.-A. 1999. Technology's links and *chaînes*: the processual unfolding of technique and technician. In: M. Dobres and C. Hoffman (eds.) *The Social Dynamics of Technology: Practice, Politics and World Views.* 124-146. Washington: Smithsonian Institute Press

Dobres, M.-A. 2000. *Technology and Social Agency: outlining a practice framework for archaeology.* Oxford: Blackwell

Dobres, M.-A. 2010. Archaeologies of technology. *Cambridge Journal of Economics* 34: 103-114

Dobres, M.-A. and Hoffman, C. 1999. Introduction: a context for the present and future of technology studies. In: M. Dobres and C. Hoffman (eds.) *The Social Dynamics of Technology: Practice, Politics, and World Views.* 1-19. Washington: Smithsonian Institution Press

Dornan, J. 2002. Agency and archaeology: past, present, and future directions. *Journal of Archaeological Method and Theory* 9: 303-329

Doyle, S. 1998. *An environmental history of the kingdom of Bunyoro in western Uganda, from c.1860 to 1940.* Cambridge: Cambridge University Press

Doyle, S. 2000. Population decline and delayed recovery in Bunyoro, 1860-1960. *Journal of African History* 41: 429-458

Doyle, S. 2006a. *Crisis and Decline in Bunyoro: population and environment in Western Uganda 1860-1955.* Oxford: James Currey

Doyle, S. 2006b. From Kitara to the lost counties: genealogy, land and legitimacy in the kingdom of Bunyoro, western Uganda. *Social Identities* 12: 457-470

Doyle, S. 2007. The Cwezi-Kubandwa Debate: gender, hegemony and pre-colonial religion in Bunyoro, western Uganda. *Africa* 77: 559-581

Drewal, H. 1996. Past as prologues: empowering Africa's cultural institutions. In: P. Schmidt and R. McIntosh (eds.) *Plundering Africa's Past.* 110-124. Bloomington: Indiana University Press

Dunbar, A. 1965. *A History of Bunyoro-Kitara*. Nairobi: Oxford University Press

Dupré, M.-C. and Pinçon, B. 1997. *Métallurgie et politique en Afrique: deux mille ans sur les Plateaux Bateké.* Paris: Harmattan

Echard, N. 1968 *Noces du feu*. Paris: Centre Nationale de la Recherche Scientifique/Comité du Film Ethnographique (Musée de l'Homme)

Eerkens, J. and Lipo, C. 2005. Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record. *Journal of Anthropological Archaeology* 24: 316-334

Eerkens, J. and Lipo, C. 2007. Cultural Transmission Theory and the Archaeological Record: Providing Context to Understanding Variation and Temporal Changes in Material Culture. *Journal of Archaeological Research* 15: 239-274

Ehret, C. 2000. Testing the Expectations of Glottochronology against the Correlations of Language and Archaeology in Africa. In: C. Renfrew, A. McMahon and L. Trask (eds.) *Time Depth in Historical Linguistics*. 373-399. Cambridge: McDonald Institute for Archaeological Research

Eliade, M. 1962. *The Forge and the Crucible*. [trans. S. Corrin] New York: Harper and Brothers

Ellison, J. 1996. The future of African archaeology. *African Archaeological Review* 13: 5-7

Esterhuysen, A. 2000. The birth of educational archaeology in South Africa. *Antiquity* 74: 159-164

Fisher, A. 1911. *Twilight Tales of the Black Baganda*. London: Marshall Brothers

Flanagan, F. 1984. Three USGS mafic rock reference samples, W-2, DNC-1, and BIR-1. *U.S. Geological Survey Bulletin* 1623: 54

Fletcher, R. 1998. African Urbanism: scale, mobility and transformations. In: G. Connah (ed.) *Transformations in Africa: essays on Africa's later past.* 104-138. London: Leicester University Press

Foucault, M. 1969. *The Archaeology of Knowledge*. London: Routledge

Fowler, I. 1990. Babungo: A Study of Iron Production, Trade and Power in Nineteenth Century Ndop Plain Chiefdom (Cameroon). Unpublished PhD thesis. London: UCL

Freestone, I. and Tite, M. 1986. Refractories in the Ancient and Preindustrial World. In: W. Kingery (ed.) *High-Technology Ceramics: the nature of innovation and change in ceramic technology*. 35-62. Westerville: The American Ceramic Society

Furley, O. 1959. The Sudanese Troops in Uganda. *African Affairs* 58: 311-328

Gardner, A. 2007. *An Archaeology of Identity: soldiers and society in Late Roman Britain*. Walnut Creek: Left Coast Press

Gardner, A. 2008. Agency. In: R. Bentley, H. Maschner, and C. Chippindale (eds.) *Handbook of archaeological theories*. 96-108. Plymouth: AltaMira Press

Gautier, A. 2001. Luminescence dating of archaeometallurgical slag: use of the SAR technique for determination of the burial dose. *Quaternary Science Reviews* 20: 973-980

Guildeson, T., Reimer, P., Brown, T. 2005. The boon and bane of radiocarbon dating. *Science* 307: 362-364

Giblin, J. 2003. *The Royal Potters of Buganda: A Social and Symbolic Study*. Unpublished MA dissertation. London: UCL

Giblin, J. 2008. New work on the later archaeology of Rwanda 2006 to 2007: a preliminary fieldwork report. *Nyame Akuma* 69: 45-55

Giblin, J. 2010. *Re-Constructing the Past in Post-Genocide Rwanda: An Archaeological Contribution*. Unpublished PhD thesis. London: UCL

Giblin, J., Humphris. J., Clements, A., forthcoming. An Urewe Burial in Rwanda: Pathologies, Metallurgy and Long Distance Trade ca. 400 AD. *Azania: archaeological research in Africa*

Giddens, A. 1984. *The Constitution of Society: An Outline of Theory of Structuration*. Berkeley: University of California

Gilchrist, J. 1989. *Extraction Metallurgy*. London: Pergamon

Giles, M. 2007. Making metal and forging relations: ironworking in the British Iron Age. *Oxford Journal of Archaeology* 26: 395-413

Godfrey, E., Vizcaino, A. and McDonnell, J. 2003. The role of phosphorous in early ironworking. In: L. Nørbach (ed.) *Prehistoric and medieval direct iron smelting in Scandinavia and Europe: aspects of technology and science*. 191-193. Aarhus: Aarhus University Press

Goody, J. 1971. *Technology, Tradition and the State in Africa.* Oxford: Oxford University Press

Gorju, J. 1920. *Entre le Victoria, l'Albert et l'Edouard; ethnographie de la partie anglaise du vicariat de l'Uganda: origins, histoire, religion, coutumes.* Rennes: Oberthür

Gosden, C. 2001. Postcolonial archaeology. Issues of culture, identity, and knowledge. In: I. Hodder (ed.) *Archaeological Theory Today*. 241-261. Cambridge: Polity Press

Gosselain, O. 1992. Technology and Style: Potters and pottery among the Bafia of Cameroon. *Man* 27: 259-286

Gould, R. 1978. Beyond Analogy in Ethnoarchaeology. In: R. Gould (ed.) *Explorations in Ethnoarchaeology*. 249-294. Albuquerque: University of New Mexico Press

Gouthama and Balasubramaniam, R. 2003. Alloy design of ductile phosphoric iron: ideas from archaeometallurgy. *Bulletin of Materials Science* 26: 483-491

Grant, J. 1864. *A Walk Across Africa: or domestic scenes from my Nile journal.* London: William Blackwood and Sons

Grosz-Ngaté, M. 1988. Power and Knowledge. The representation of the Mande world in the works of Park, Caillié, Monteil, and Delafosse. *Cahiers d'Études Africaines* 28: 485-511

Guildeson, T., Reimer, P., Brown, T. 2005. The boon and bane of radiocarbon dating. *Science* 307: 362-364

Hartley, L. P. (1953). *The Go-Between*. London: Hamish Hamilton

Hassan, F. 1999. African Archaeology: the call of the future. *African Affairs* 98: 393-406

Hauptmann, A. 2007. *The Archaeometallurgy of Copper: evidence from Faynan, Jordan.* Berlin: Springer-Verlag

Haustein, M., Roewer, G., Krbetschek, M., Pernicka, E. 2003. Dating archaeometallurgical slags using thermoluminescence. *Archaeometry* 45: 519-530

Hedges, R. and Salter, C. 1979. Source determination of iron currency bars through analysis of the slag inclusions. *Archaeometry* 21: 161-175

Hegel, G. 1899 [trans. Sibree 2007]. *The Philosophy of History*. New York: Cosimo

Hegmon, M. 1998. Technology, Style and Social Practices: archaeological approaches. In: M. Stark (ed.) *The Archaeology of Social Boundaries*. 264-279. Washington: Smithsonian Institution Press

Heizer, R. 1962. The background of Thomsen's three-age system. *Technology and Culture* 3: 259-266

Helms, M. 1993. *Craft and the Kingly Ideal.* Austin: University of Texas Press

Henige, D. 1974. *The Chronology of Oral Tradition: quest for a chimera.* Oxford: Oxford University Press

Henige, D. 1980. The disease of writing: Ganda and Nyoro kinglists in a newly literate world. In: J. Miller (ed.) *The African Past Speaks: essays on oral tradition and history.* 240-261. Hamden: Dawson Archon

Herbert, E. 1993. *Iron, Gender and Power: rituals of transformation in African societies.* Indianapolis: Indiana University Press

Hesse, P. 1995. A chemical and physical study of the soils of termite mounds in East Africa. *Journal of Ecology* 43: 449-461

Hiernaux, J. and Maquet, E. 1960. Cultures préhistoriques de l'âge des métaux aux Ruanda-Urundi et au Kivu (Congo Belge). *Bulletin des Sciences de L'Academie Royals des Sciences Coloniale*

Hiernaux, J. and Maquet, E. 1968. *L'Age du Fer à Kibiro (Uganda)*, Museé Royal de l'Afrique Centrale, Tervuren, Belgium, Annales serie in-8°, Sciences Humaines, No. 63

Hinde, C. 2007. (ed.) Uganda. *Mining Journal special publication.* December 2007

Hjärthner-Holder, E. and Risberg, C. 2003. The introduction of iron in Sweden and Greece. In: L. Nørbach (ed.) *Prehistoric and medieval direct iron smelting in Scandinavia and Europe: aspects of technology and science.* 83-86. Aarhus: Aarhus University Press

Hodder, I. 2001. Introduction: a review of contemporary theoretical debates in archaeology. In: I. Hodder (ed.) *Archaeological Theory Today.* 1-13. Cambridge: Polity Press

Holl, A. 1990. West African archaeology: colonialism and nationalism. In: P. Robertshaw (ed.) *A History of African Archaeology.* 296-308. London: James Currey

Holl, A. 2009. Early West African Metallurgies: New Data and Old Orthodoxy. *Journal of World Prehistory* 22: 415-438

Horton, R. 1993. *Patterns of Thought in African and the West: essays on magic, religion and science.* Cambridge: Cambridge University Press

Hosler, D. 1994. *The Sounds and Colors of Power: the sacred metallurgical technology of ancient West Mexico.* Cambridge, MA: MIT Press

Huffman, T. N. 1989. Ceramics, settlements and late Iron Age migrations. *African Archaeological Review* 7: 155-182

Humphris, J. 2002. *An Ethno-Historic Investigation of Iron Smelting in the Buganda Kingdom.* Unpublished BA dissertation. Manchester: Manchester University

Humphris, J. 2004. *Reconstructing a Forgotten Industry: an investigation of iron smelting in Buganda*. Unpublished MA dissertation. London: UCL

Humphris, J. 2008. Iron production in southern Rwanda: a summary of recent research. *Nyame Akuma* 70: 2-10

Humphris, J. 2010. *An Arcaheometallurgical Investigation of Iron Smelting Traditions in Southern Rwanda*. Unpublished PhD thesis. London: UCL

Humphris, J. and Iles, L. forthcoming. Pre-colonial iron production in Great Lakes Africa: recent archaeometallurgical research at the UCL Institute of Archaeology. In: J. Humphris and H. Veldhuijzen (eds.) *Proceedings of the World of Iron Conference, London 2009*

Humphris J., Martinón-Torres, M., Rehren, Th. and Reid, A., 2009. Variability in single smelting episodes – a pilot study using iron slag from Uganda. *Journal of Archaeological Science* 36: 359-369

Huysecom, E. and Agustoni, B. 1997. *Inagina, l'ultime maison du fer.* Film. Geneva: Huysecom, Agustoni, and PAVE

Iles, L. 2004. *Supporting the Smelt: an archaeological investigation into the selection and use of plants within the Buganda iron smelting tradition.* Unpublished BSc dissertation. London: UCL

Iles, L. 2006. *An Archaeometallurgical Investigation of Pastoralist Iron Production on the Laikipia Plateau, Kenya*. Unpublished MSc dissertation. London: UCL

Iles, L. 2009a. Pre-Colonial Iron Production in Western Uganda: recent survey and excavation. *Nyame Akuma* 71: 35-45

Iles, L. 2009b. Impressions of banana pseudostem in iron slag from eastern Africa. *Ethnobotany Research and Applications* 7: 283-291

Iles, L. and Childs, S. T. forthcoming. Ethnoarchaeological and historical methods. In: C. Thornton and B. Roberts (eds.) *A Global Perspective in Early Metallurgy*. New York: Springer

Iles, L. and Martinón-Torres, M. 2009. Pastoralist iron production on the Laikipia Plateau, Kenya: wider implications for archaeometallurgical studies. *Journal of Archaeological Science* 36: 2314-2326

Iles, L. forthcoming. Applying ethnographic presents to archaeological pasts: the relevance of memories of iron production in western Uganda. In: J. Humphris and H. Veldhuijzen (eds.) *Proceedings of the World of Iron Conference, London 2009*

Ineson, P. 1989. *Introduction to Practical Ore Microscopy*. Harlow: Longman

Ingham, K. 1953. The amagasani of the Abakama of Bunyoro. *Uganda Journal* 17: 138-145

Ingham, K. 1957. Some aspects of the history of Western Uganda. *Uganda Journal* 21: 131-149

Ingham, K. 1975. *The Kingdom of Toro in Uganda*. London: Methuen

Insoll, T. 2004. A true picture? Colonial and other historical archaeologies. In: A. Reid and P. Lane (eds.) *African Historical Archaeologies*. 163-187. New York: Kluwer

Jeffreys, M. 1952. Some notes on the Bikom blacksmiths. *Man* 52: 49-51

Johnson, M. 2010. *Archaeological Theory: an introduction.* Oxford: Wiley-Blackwell

Johnston, H. 1902. *The Uganda Protectorate.* London: Hutchinson

Jolly, D., Taylor, D., Marchant, R., Hamilton, A., Bonnefille, R., Buchet, G. and Riollet, G. 1997. Vegetation dynamics in central Africa since 18,000 years BP: pollen records from the interlacustrine highlands of Burundi, Rwanda and western Uganda. *Journal of Biogeography* 24: 495-512

Jones, D. 2001. *Archaeometallurgy* (Centre for Archaeology Guidelines Series). Swindon: English Heritage

Jones, A. 2002. *Archaeological theory and scientific practice.* Cambridge: Cambridge University Press

Joosten, I. 2004. *Technology of Early Historical Iron Production in the Netherlands.* Amsterdam: Vrije University

Juleff, G. 1996. An ancient wind-powered iron smelting technology in Sri Lanka. *Nature* 379: 60-63

Juleff, G. 1998. *Early Iron and Steel in Sri Lanka. A Study of the Samanalawewa Area.* Verlag: Philipp von Zabern

Juleff, G. 2009. Technology and evolution: a root and branch view of Asian iron from first-millennium bc Sri Lanka to Japanese steel. *World Archaeology* 41: 557-577

Kagwa, A. 1918. *Ekitabo Kya Mpisa za Baganda* Kampala: Fountain Publishers

Karugire, S. 1971. *A History of the Kingdom of Nkore in Western Uganda to 1896*. Oxford: Clarendon Press

Kearns, T. Martinón-Torres, M. and Rehren, Th. forthcoming. Metal to mould: alloy identification in experimental casting moulds using XRF. *Historical Metallurgy*

Kihumuro-Apuuli, D. 1994. *A Thousand Years of Bunyoro-Kitara Kingdom: the kingdom and the rulers*. Kampala: Fountain

Kikonyogo, R. 2010. History beckons Mubende stone mysteries. *Daily Monitor,* Kampala, Uganda [internet] 4 September. Retrieved on 21 September 2010 from World Wide Web: http://www.monitor.co.ug/News/National/-/688334/1003206/-/item/0/-/elf62l/-/index.html

Killick, D. 1991. The Relevance of Recent African Iron-Smelting Practice to Reconstructions of Prehistoric Smelting Technology. In: P. Glumac (ed.) *Recent Trends in Archaeometallurgical Research.* 47-54. Philadelphia: MASCA

Killick, D. 2004a. What do we know about African iron working? *Journal of African Archaeology* 2: 97-112

Killick, D. 2004b. Social constructionist approaches to the study of technology. *World Archaeology* 36: 571-578

Killick, D. 2009. Cairo to Cape: the spread of metallurgy through eastern and southern Africa. *Journal of World Prehistory* 22: 399-414

Kiwanuka, J. 1968a. The Empire of Bunyoro-Kitara: myth or reality. *Canadian Review of African Studies* 2: 27-48

Kiwanuka, J. 1968b. Bunyoro and the British: a reappraisal of the decline and fall of an African kingdom. *The Journal of African History* 9: 603-619

Kodesh, N. 2008. Networks of Knowledge: clanship and collective well-being in Buganda. *Journal of African History* 49: 197-216

Kopytoff, I. 1987. *The African Frontier: the reproduction of traditional African systems.* Bloomington: Indiana University Press

Kresten, P. and Hjärthener-Holdar, E. 2001. Analyses of the Swedish Ancient Iron Reference Slag W-25:R. *Historical Metallurgy* 35: 48-51

Kusimba, C. and Kusimba, S. 2005. Mosaics and Interactions: East Africa, 2000 bp to the Present. In: A. Stahl (ed.) *African Archaeology*. 392- 419. Oxford: Blackwell

Lane, P. 1994/1995. The use and abuse of ethnography in southern Africa. *Azania* 29/30: 50-56

Lane, P. 1996. Rethinking ethnoarchaeology. In: G. Pwiti and R. Soper (eds.) *Aspects of African Archaeology: Papers from the 10th Pan-African Congress of Prehistory and Related Studies*. 727-731. Harare: University of Zimbabwe Publications

Lane, P. 2006. Present to Past: ethnoarchaeology. In: Tilley C. (ed.) *Handbook of Material Culture.* 402-425. London: SAGE

Lane, P., Ashley, C. and Oteyo, G. 2006. New dates for Kansyore and Urewe wares from Northern Nyanza, Kenya. *Azania* 41: 123-138

Lane, P., Ashley, C., Seitsonen, O., Harvey, P., Mire, S. and Odede, F. 2007. The transition to farming in Eastern Africa: New faunal and dating evidence from Wadh Lang'o and Usenge, Kenya. *Antiquity* 81: 62-81

Lanning, E. 1953. Ancient earthworks in Western Uganda. *Uganda Journal* 17: 51-62

Lanning, E. 1954. Genital Symbols on Smiths' Bellows in Uganda*. Man* 54: 167-169

Lanning, E. 1958. Shafts in Buganda and Toro. *Uganda Journal* 22: 188-189

Lanning, E. 1970. Ntusi: an ancient capital site in Western Uganda. *Azania* 5: 39-54

Lanning, E. 1979. Cylindrical Pits in Uganda. *Azania* 14: 143-147

Leakey, L. 1931. *The stone age cultures of Kenya Colony.* Cambridge: Cambridge University Press

Lechtman, H. 1977. Style in Technology: some early thoughts. In: H. Lechtman and R. S. Merrill (eds.) *Material Culture: style organization and dynamics of technology.* 3-20. St Paul: West Publishing Company

Lechtman, H. 1984. Andean value systems and the development of prehistoric metallurgy. *Technology and Culture* 25: 1-36

Lejju, J. 2009. Vegetation dynamics in western Uganda during the last 1000 years: climate change or human induced environmental degradation? *African Journal of Ecology* 47: 21-29

Lejju, B., Robertshaw, P. and Taylor, D. 2003. Vegetation history and archaeology at Munsa, western Uganda. *Azania* 38: 155-165

Lejju, B., Robertshaw, P. and Taylor, D. 2006. Africa's earliest bananas? *Journal of Archaeological Science* 33: 102-113

Lemonnier, P. 1986. The study of material culture today: towards an anthropology of technical systems. *Journal of Anthropological Archaeology* 5: 147-186

Lemonnier, P. 1992. *Elements for an Anthropology of Technology*. Michigan: University of Michigan

Leroi-Gourhan, A. 1945. *Evolution et Techniques, vol. 2: milieu et techniques*. Paris: Albin Michel

Leroi-Gourhan, A. 1964. *La Geste et la Parole I: Technique et Langage*. Paris: Albin Michel

London, G. 1991. Standardization and variation in the work of craft specialists. In: W. Longacre (ed.) *Ceramic Ethnoarchaeology*. 182-204. Tuscon: University of Arizona Press

Lubbock, J. 1865. *Pre-Historic Times: as Illustrated by Ancient Remains, and the Manners and Customs of Modern Savages*. London: Williams and Norgate

Lugan, B. 1983. Le Rwanda oriental. In: F. van Noten (ed.) *Histoire archeologique du Rwanda*. 130-6. Tervuren: Musée Royal de l'Afrique Centrale

MacLean, R. 1994/1995. Late Stone Age and Early Iron Age settlement in the Interlacustrine region: a district case study. *Azania* 29/30: 296-302

MacLean, R. 1996. The Social Impact of the Beginnings of Iron Technology in the Western Lake Victoria Basin: a district case study. Unpublished PhD thesis. Cambridge: University of Cambridge

Maddox, H. 1902. *An Elementary Lunyoro Grammar*. London: Society for Promoting Christian Knowledge

Mahachi, G. and Ndoro, W. 1997. The socio-political context of southern African Iron Age studies with special reference to Great Zimbabwe. In: G. Pwiti (ed.) *Caves, Monuments and Texts: Zimbabwean archaeology today*. 89-108. Uppsala: Department of Archaeology and Ancient History

Mair, L. 1934. *An African people in the twentieth century*. London: Routledge

Mapunda, B. 2010. *Contemplating the Fipa Ironworking*. Kampala: Fountain Publishers

Maquet, E. 1965. Outils de forge du Congo, du Rwanda et du Burundi. *Annales Nouvelle série in-4o. Science humaines*. Koninklijk Museum voor Midden-Afrika 5

Marchant, R. and Taylor, D. 1998. Dynamics of montane forest in central Africa during the late Holocene: a pollen-based record from western Uganda. *The Holocene* 8: 375-381

Martinón-Torres, M., Rehren, Th. and Freestone, I. 2006. Mullite and the mystery of Hessian wares. *Nature* 444: 437-438

Mathew, G. 1953. Recent discoveries in East African archaeology. *Antiquity* 27: 212-218

Mauss, M. 1935. Les Techniques du Corps. In: B. Brewster (ed.) *Sociology and Psychology: essays of Marcel Mauss*. London: Routledge

McIntosh, S. 1999. Pathways to complexity: an African perspective. In: S. McIntosh (ed.) *Beyond Chiefdoms: pathways to complexity*. 1-30. Cambridge: Cambridge University Press

Merkel, J. and Barrett, B. 2000. The adventitious production of iron in the smelting of copper revisited: metallographic evidence against a tempting model. *Historical Metallurgy* 34: 59-66

Meskell, L. 2002. The intersections of identity and politics in archaeology. *International Journal of Historical Archaeology* 31: 279-301

Mikkelsen, P. 1997. Straw in Slag-Pit Furnaces. In: L. Nørbach (ed.) *Early Iron Production – archaeology, technology and experiments*. 63-66. Historical-Archaeological Experimental Centre, Technical Report No. 3

Mikkelsen, P. 2003. Slag – with an impression of agricultural practices. In: L. Nørbach (ed.) *Prehistoric and Medieval Direct Iron Smelting in Scandinavia and Europe: aspects of technology and science*. 43-48. Aarhus: Aarhus University Press

Miller, D. and van der Merwe, N. 1994. Early metal working in sub-Saharan Africa: a review of recent research. *Journal of African History* 35: 1-36

Miller, D., Killick, D. and van der Merwe, N. 2001. Metal working in the Northern Lowveld, South Africa, AD 1000-1890. *Journal of Field Archaeology* 28: 401-417

Misago, K. and Shumbusho, G. 1992. Archaeological and Ethnorchaeological Research in the Zones of Rutshuru and Masisi in Northern Kivu. *Nyame Akuma* 38: 66-71

Mitchell, P. 2002. *The Archaeology of Southern Africa*. Cambridge: Cambridge University Press

MoLAS. 1994. *Archaeological Site Manual*. London: Museum of London Archaeology Service

Mulkay, M. 1978. Science and the Sociology of Knowledge. London: George Allen and Unwin

Ndoro, W. 1994. The preservation and presentation of Great Zimbabwe. *Antiquity* 68: 616-623

Ndoro, W. 2005. *The Preservation of Great Zimbabwe: your monument, our shrine*. Rome: ICCROM

Nesse, W. 2004. *Introduction to Optical Mineralogy*. Oxford: Oxford University Press

Nyakatura. J. 1973 [1947] Abakama ba Bunyoro Kitara. Kampala (trans. T. Muganwa). In: G. Uzoigwe (ed.) *Anatomy of an African Kingdom: a history of Bunyoro-Kitara*. New York: Doubleday

O'Brien, T. 1939. *The Prehistory of the Uganda Protectorate.* Cambridge: Cambridge University Press

O'Brien, M. and Leonard, R. 2001. Style and Function: an introduction. In: T. Hurt and G. Rakita (eds.) *Style and Function: Conceptual Issues in Evolutionary Archaeology*. 1-24. Westport: Bergin and Garvey

Ogot, B. 1984. The Great Lakes Region. In: D. Niane (ed.) *Africa From the Twelfth to the Sixteenth Century*. 498-524. Paris: UNESCO

Oliver, R. 1953. A question about the Bachwezi. *Uganda Journal* 17: 135-137

Oliver, R. 1955. The Traditional Histories of Buganda, Bunyoro, and Nkole. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland* 85: 111-117

Oliver, R. 1977. The East African Interior. In: R. Oliver (ed.) *The Cambridge History of Africa from c.1050 to c. 1600.* 621-669. Cambridge: Cambridge University Press

Oliver, R. 1982. The Nilotic contribution to Bantu Africa. *Journal of African History* 23: 433-442

Orton, C. 2000. *Sampling in Archaeology*. Cambridge: Cambridge University Press

Ottaway, B. 2001. Innovation, production and specialization in early prehistoric copper metallurgy. *European Journal of Archaeology* 4: 87-112

Papousek, D. 1989. Technological change as social rebellion. In: S. van der Leeuw and R. Torrence (eds.) *What's New? A closer look at the process of innovation.* 140-166. London: Unwin Hyman

Paynter, S. 2006. Regional Variations in Bloomery Smelting Slag of the Iron Age and Romano-British Periods. *Archaeometry* 48: 271-292

Pfaffenberger, B. 1992. Social anthropology of technology. *Annual Review of Anthropology* 21: 491-516

Pleiner, R. 2000. *Iron In Archaeology. The European Bloomery Smelters.* Praha: Archeologický Ústav Avcr

Pollard, M. and Heron, C. 1996. *Archaeological Chemistry.* Cambridge: Royal Society of Chemistry

Posnansky, M. 1961a. Pottery types from archaeological sites in East Africa. *Journal of African History* 2: 177-198

Posnansky, M. 1961b. Dimple-based pottery from Uganda. *Man* 168: 141-142

Posnansky, M. 1966. Kingship, archaeology and historical myth. *Uganda Journal* 30: 1-12

Posnansky, M. 1969. Bigo bya Mugenyi. *Uganda Journal* 33: 125-150

Preßlinger, H. 2008. Ferrum Noricum – archaeometallurgy of slags and steel products. In: B. Cech (ed.) *The Production of Ferrum Noricum at the Hüttenberger Erzberg: the results of interdisciplinary research at Semlach/Eisner between 2003-2005.* 232-250. Vienna: OGA

Pryce, O., Pigott, V.C., Martinon-Torres, M. and Rehren, Th. 2010. Prehistoric copper production and technological reproduction in the Khao Wong Prachan Valley of Central Thailand. *Archaeological and Anthropological Sciences.* Online first view

Pwiti, G. 2000. Book review: 'Archaeology Africa (1996)' *African Archaeological Review* 17: 45-47

Pwiti, G. and Ndoro, W. 1999. The legacy of colonialism: perceptions of the Cultural Heritage in southern Africa, with special reference to Great Zimbabwe. *African Archaeological Review* 16: 143-153

Radivojevic, M., Rehren, Th., Pernicka, E., Sljivar, D., Brauns, M. and Boric, D. 2010. On the origins of extractive metallurgy: new evidence from Europe. *Journal of Archaeological Science* 37: 2775-2787

Randall-MacIver, D. 1906. The Rhodesia Ruins: their probable origin and significance. *The Geographical Journal* 27: 325-336

Ray, B. 1991. *Myth, Ritual and Kingship in Buganda.* Oxford: Oxford University Press

Raymaekers, J. and Van Noten, F. 1986. Early iron furnaces with 'bricks' in Rwanda: complimentary evidence from Mutwarubona. *Azania* 21: 65-84

Rehder, J. 2000. *The Mastery and Uses of Fire in Antiquity.* London: McGill-Queen's University Press

Rehren, Th. 2001. Meroe, iron and Africa. *Mitteilungen der Sudanarchäologischen Gesellschaft* 12: 102-109

Rehren, Th. and Papakhristu, O. 2000. Cutting edge technology – The Ferghana Process of medieval crucible steel smelting. *Metalla (Bochum)* 7: 55-69

Rehren, Th. and Papachristou, O. 2003. Similar like white and black: a comparison of steel-making crucibles from Central Asia and the Indian subcontinent. In: Th. Stoellner, G. Koerlin, G. Steffens and J. Cierny (eds.) *Man and Mining - Mensch und Bergbau. Studies in Honour of Gerd Weisgerber.* 393-404. Der Anschnitt, Beiheft 16: Bochum

Rehren, Th., Charlton, M., Chirikure, S., Humphris, J., Ige, A. and Veldhuijzen, H. 2007. Decisions set in slag – the human factor in African iron smelting. In: S. LaNiece, D. Hook and P. Craddock (eds.) *Metals and mines – studies in archaeometallurgy*. 211-218. London: Archetype

Reid, D. A. M. 1990. Ntusi and its hinterland: further investigations of the Later Iron Age and pastoral ecology in Southern Uganda. *Nyame Akuma* 33: 26-28

Reid, D. A. M. 1991. *The Role of Cattle in the Later Iron Age Communities of Southern Uganda*. Unpublished PhD Thesis. Cambridge: University of Cambridge

Reid, D. A. M. 1994/1995. Early settlement and social organization in the Interlacustrine region. *Azania* 29/30: 303-313

Reid, D. A. M. 1996. Ntusi and the development of social complexity in southern Uganda. In: G. Pwiti and R. Soper (eds.) *Aspects of African Archaeology*. 621-628. Harare: University of Zimbabwe Press

Reid, D. A. M. 2003. Recent research on the archaeology of Buganda. In: P. Mitchell, A. Haour and J. Hobart (eds.) *Researching Africa's Past.* 110-117. Oxford: Oxbow

Reid, R. 2002. *Political Power in Pre-colonial Buganda: economy, society and welfare in the nineteenth century*. London: James Currey

Reid, D. A. M. and MacLean, R. 1995. Symbolism and the social context of iron production in Karagwe. *World Archaeology* 27: 144-161

Reid, D. A. M. and Meredith, J. 1993. Houses, pots and more cows: the 1991 excavation season at Ntusi. *Nyame Akuma* 40: 58-61

Reid, D. A. M. and Njau, J. 1994. Archaeological research in Karagwe District. *Nyame Akuma* 41: 68-73

Reid, D. A. M. and Young, R. 2003. Iron-smelting and bananas in Buganda. In: P. Mitchell, A. Haour and J. Hobart (eds.) *Researching Africa's Past.* 118-123 Oxford: Oxbow

Reimer, P., Baillie, M., Bard, E., Bayliss, A., Beck, J., Blackwell, P., Bronk Ramsey, C., Buck, C., Burr, G., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kaiser, K., Kromer, B., McCormac, F., Manning, S., Reimer, R., Richards, D., Southon, J., Talamo, S., Turney, C., van der Plicht, J., and Weyhenmeyer, C. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. *Radiocarbon* 51: 1111-1150

Renfrew, C. 1973. *Before Civilisation, the Radiocarbon Revolution and Prehistoric Europe.* London: Cape

Renfrew, C. 2000. At the edge of knowability: towards a prehistory of languages. *Cambridge Archaeological Journal* 10: 7-34

Rice, P. 1981. Evolution of specialized pottery production: a trial model. *Current Anthropology* 22: 219-240

Rice, P. 1991. Specialization, Standardization, and Diversity: a retrospective. In: R. Bishop and F. Lange (eds.) *The Ceramic Legacy of Anna O. Shepard.* 257-79. Colorado: University of Colorado Press

Roberts, B., Thornton, C. and Pigott, V. 2009. Development of metallurgy in Eurasia. *Antiquity* 83: 1012-1022

Robertshaw, P. 1990. A History of African Archaeology: an introduction. In: P. Robertshaw (ed.) *A History of African Archaeology.* 3-12. Oxford: James Currey

Robertshaw, P. 1991a. Recent Archaeological Survey in Western Uganda. *Nyame Akuma* 36: 40-46

Robertshaw, P. 1991b. Unpublished fieldwork notes

Robertshaw, P. 1994. Archaeological survey, ceramic analysis, and state formation in western Uganda. *African Archaeological Review* 12: 105-131

Robertshaw, P. 1997. Munsa earthworks. *Azania* 32: 1-20

Robertshaw, P. 1999. Seeking and keeping power in Bunyoro-Kitara, Uganda. In: S. McIntosh (ed.) *Beyond Chiefdoms: pathways to complexity in Africa.* 136-150. Cambridge: Cambridge University Press

Robertshaw, P. 2003. The origins of the state in east Africa. In: C. Kusimba and S. Kusimiba (eds.) *East African Archaeology: Foragers, Potters, Smiths and Traders.* Philadelphia: University of Pennsylvania

Robertshaw, P. 2004. African historical archaeology(ies): past, present and a possible future. In: D. A. M. Reid and P. Lane (eds.) *African Historical Archaeologies.* 375-392. New York: Kluwer Academic

Robertshaw, P. 2010. Beyond the Segmentary State: creative and instrumental power in western Uganda. *Journal of World Prehistory* 23: 255-269

Robertshaw, P. and Taylor, D. 2000. Climate change and the rise of political complexity in western Uganda. *Journal of African History* 41: 1-28

Robertshaw, P., Kamuhangire, E., Reid, A., Young, R., Childs, S. T. and Pearson, N. 1997. Archaeological research in Bunyoro-Kitara: preliminary results. *Nyame Akuma* 48: 70-77

Robertshaw, P., Taylor, D., Doyle, S. and Marchant, R. 2004. Famine, climate and crisis in western Uganda. In: R. Battarbee, F. Gasse and C. Stickley (eds.) *Past Climate Variability through Europe and Africa.* 193-549. Amsterdam: Kluwer

Roscoe, J. 1911. *The Baganda*. London: Macmillan and Co.

Roscoe, J. 1915. *The Northern Bantu: an account of some central African tribes of the Uganda Protectorate*. Cambridge: Cambridge University Press

Roscoe, J. 1923. *The Bakitara or Banyoro.* Cambridge: Cambridge University Press

Rostoker, W. and Bronson, B. 1990. *Pre-Industrial Iron: its technology and ethnology.* Archaeomaterials Monograph No. 1. Philadelphia: Pennsylvania University Press

Roux, V. 2003. Ceramic Standardization and Intensity of Production: quantifying degrees of specialization. *American Antiquity* 68: 768-782

Rowlands, M. 1971. The archaeological interpretation of prehistoric metalworking. *World Archaeology* 3: 210-224

Rowlands, M. 1995. The archaeology of colonialism and constituting the African peasantry. In: D. Miller, M. Rowlands and C. Tilley (eds.) *Domination and Resistance.* 261-283. London: Routledge

Rowlands, M. and Warnier, J.-P. 1993. The magical production of iron in the Cameroon Grassfields. In: T. Shaw, P. Sinclair, B. Andah and A. Okpoko (eds.) *The Archaeology of Africa: Food, Metals and Towns.* 512-550. London: Routledge

Rwabwogo, M. 2005. *Uganda Districts Information Handbook: expanded edition 2005-2006.* Kampala: Fountain Publishers

Rye, O. 1981. *Pottery Technology: principles and reconstruction.* Washington: Taraxacum

Sackett, J. 1985. Style and ethnicity in the Kalahari: a reply to Wiessner. *American Antiquity* 50: 158-159

Saltman, C., Goucher, C. and Herbert, E. 1986. *The Blooms of Banjeli: Technology and Gender in African iron making, Ghana.* Film

Sassoon, H. 1983. Kings, cattle and blacksmiths: royal insignia and religious symbolism in the interlacustrine states. *Azania* 18: 93-106

Schlanger, N. 1994. Mindful technology: unleashing the chaîne opératoire for an archaeology of mind. In: C. Renfrew and E. Zubrow (eds.) *The Ancient Mind: elements for cognitive archaeology*. Cambridge: Cambridge University Press

Schmidt, P. 1978. *Historical Archaeology: A Structural Approach in an African Culture.* Westport: Greenwood Press

Schmidt, P. 1990. Oral traditions, archaeology and history: a short reflective history. In: P. Robertshaw (ed.) *A History of African Archaeology*. 252-270. Oxford: James Currey

Schmidt, P. 1995. Using archaeology to remake history in Africa. In: P. Schmidt and T. Patterson (eds.) *Making Alternative Histories*. 119-147. Santa Fe: School of American Research Press

Schmidt, P. 1996. Reconfiguring the Barongo: reproductive symbolism and reproduction among a work association of iron smelters. In: P. Schmidt (ed.) *The Culture and Technology of African Iron Production.* 74–127. Gainesville: University of Florida Press

Schmidt, P. 1997. *Iron Technology in East Africa: symbolism, science and archaeology*. Indiana: James Currey

Schmidt, P. 1998. Reading gender in the ancient iron technology of Africa. In: S. Kent (ed.) *Gender in African Prehistory.* 139-162. Walnut Creek: Altamira

Schmidt, P. 2001. Resisting homogenisation and recovering variation and innovation in African iron smelting. *Journal of Mediterranean Archaeology* 14: 222-227

Schmidt, P. 2006. *Historical Archaeology in Africa: representation, social memory and oral histories.* Oxford: AltaMira

Schmidt, P. 2009. Tropes, Materiality, and Ritual Embodiment of African Iron Smelting Furnaces as Human Figures. *Journal of Archaeological Method and Theory* 16: 262-282

Schmidt, P. and Childs, S. T. 1985. Innovation and industry during the Early Iron Age in East Africa: KM2 and KM3 sites in Northwest Tanzania. *African Archaeological Review* 3: 53-94

Schmidt, P. and Childs, S. T. 1996. Actualistic Models for Interprtation of Two Early Iron Age Industrial Sites in Northwestern Tanzania. In: P. Schmidt (ed.) *The Culture and Technology of African Iron Production.* 186-233. Gainesville: University of Florida Press

Schmidt, P. and Mapunda, B. 1997. Ideology and the Archaeological Record in Africa: Interpreting Symbolism in Iron Smelting Technology. *Journal of Anthropological Archaeology* 16: 73-102

Schoenbrun, D. 1993a. Cattle herds and banana gardens: the historical geography of the western Great Lakes region, *c.*AD 800-1500. *African Archaeological Review* 11: 39-72

Schoenbrun, D. 1993b. We are what we eat: ancient agriculture between the Great Lakes. *The Journal of African History* 34: 1-31

Schoenbrun, D. 1994/1995. Social aspects of agricultural change between the Great Lakes, AD 500-1000. *Azania* 29/30: 270-282

Schoenbrun, D. 1998. *A Green Place, A Good Place: Agrarian Change, Gender, and Social Identity in the great Lakes Region to the Fifteenth Century*. Oxford: James Currey

Schoenbrun, D. 1999. The (in)visible roots of Bunyoro-Kitara and Buganda in the Lakes region: AD 800-1300. In: S. McIntosh (ed.) *Beyond Chiefdoms: pathways to complexity in Africa.* 136-150. Cambridge: Cambridge University Press

Schramm, R. and Heckel, J. 1998. Fast analysis of traces and major elements with ED(P)XRF using polarizing X-rays: TURBOQUANT. *Journal de Physique IV France* 8: 355-342

Schweinfurth, G., Ratzel, F., Felkin, R. and Hartlaub, G. (eds.) 1888 [trans. Mrs. R.W. Felkin] *Emin Pasha in Central Africa: being a collection of his letters and journals.* London: George Philip and Son

Seligman, C. 1930. *Races of Africa*. London: Thornton Butterworth

Service, E. 1962. *Primitive Social Organization.* New York: Random House

Shennan, S. 1991. Tradition, rationality and cultural transmission. In: R. Preucel (ed.) *Processual and Postprocessual Archaeologies.* 197-208. Carbondale: Center for Archaeological Investigations

Shennan, S. 1993. After social evolution: a new archaeological agenda? In N. Yoffee and A. Sherratt (eds.) *Archaeological Theory: Who Sets the Agenda?* 53-59. Cambridge: Cambridge University Press

Shennan, S. 1999. Cost, benefit and value in the organization of early European copper production. *Antiquity* 73: 352-363

Shimada, I. 1994. Pre-Hispanic metallurgy and mining in the Andes: recent advances and future tasks. In: A. Craig and R. West (eds.) *In Quest of Mineral Wealth: Aboriginal and Colonial Mining and Metallurgy in Spanish America*. 37-73. Los Angeles: Louisiana State University

Shinnie, P. 1960. Excavations at Bigo, 1957. *Uganda Journal* 24: 16-28

Sillar, B. and Tite, M. 2000. The challenge of 'technological choices' for materials science approaches in archaeology. *Archaeometry* 42: 2-20

Soper, R. 1985. Roulette Decoration on African Pottery: technical considerations, dating and distribution. *The African Archaeology Review* 3: 29-51

Spenser, H. 1863. *First Principles*. London: Willams and Norgate

Spring, C. 1993. *African Arms and Armour*. British Museum Press, London

Srinivasan, S. 1994. Wootz crucible steel: a newly discovered production site in south India. *Papers from the Institute of Archaeology* 5: 49-59

Stager, J., Cumming, B., and Meeker, L. 1997. A high resolution 11,400-yr diatom record from Lake Victoria, East Africa *Quaternary Research* 47: 81-89

Stahl, A. 2005. Introduction: Changing Perspectives on Africa's Pasts. In: A. Stahl (ed.) *African Archaeology: A Critical Introduction.* 1-23. Oxford: Blackwell

Steinhart, E. 1981. From 'Empire' to State: the emergency of the kingdom of Bunyoro-Kitara, c.1350-1890. In: H. Claessen and P. Skalník (eds.) *The Study of the State*. 353-370. The Hague: Mouton Publishers

Steinhart, E. 1984. The emergence of Bunyoro: the tributary mode of production and the formation of the state, 1400-1900. In: A. Salim (ed.) *State Formation in Eastern Africa.* 70-90. London: Heinemann

Stephens, R. 2007. *A History of Motherhood, Food Procurement and Politics in East-Central Uganda to the Nineteenth Century*. Unpublished PhD thesis. Chicago: Northwestern University

Stephens, R. 2009. Lineage and society in precolonial Uganda. *Journal of African History* 50: 203-221

Stewart, K. 1993. Iron Age ceramic studies in Great Lakes Eastern Africa. *African Archaeological Review* 11: 21-37

Straube, H. 1996. *Ferrum Noricum und die Stadt auf dem Magdalensberg*. Vienna: Springer-Verlag

Sutton, J. 1985. Ntusi and the 'dams'. *Azania* 20: 172-175

Sutton, J. 1987. The interlacustrine region: new work on the Later Iron Age. *Nyame Akuma* 29: 62-64

Sutton, J. 1993. The antecedents of the interlacustrine kingdoms. *Journal of African History* 34: 33-64

Sutton, J. 1998. Archaeological sites of east Africa. *Azania Special Vol. 33, British Institute in Eastern Africa, Nairobi*

Sutton, J. 2004. Unpublished fieldwork notes

Tantala, R. 1989. *The Early History of Kitara in Western Uganda*. Unpublished PhD dissertation. Madison: University of Wisconsin-Madison

Taylor, D. and Marchant, R. 1994/1995. Human impact in the Interlacustrine region: long-term pollen records from the Rukiga highlands. *Azania* 29/30: 283-295

Taylor, D. and Robertshaw, P. 2001. Sedimentary sequences in western Uganda as records of human environmental impacts. In: J. Runge (ed.) *Proceedings of the VXth INQUA Conference: Durban, South Africa 3-11 August 1999*. 63-76. Lisse: Swets and Zeitlinger

Taylor, D., Marchant, R., and Robertshaw, P. 1999. A sediment-based history of medium altitude forest in central Africa: a record from Kabata Swamp, Ndale volcanic field, Uganda. *Journal of Ecology* 87: 303-315

Taylor, D., Robertshaw, P. and Marchant, R. 2000. Environmental change and political-economic upheaval in precolonial western Uganda. *The Holocene* 10: 527-536

Thomas, J. 2004. *Archaeology and Modernity*. London: Routledge

Thompson, G. and Young, R. 1999. Fuels for the Furnace: Recent and Prehistoric Ironworking in Uganda and Beyond. In: M. van der Veen (ed.) *The Exploitation of plant resources in Ancient Africa*. 221-239. New York: Kluwer

Todd, J. and Charles, J. 1978. Ethiopian bloomery iron and the significance of inclusion analysis in iron studies. *Journal of the Historical Metallurgical Society* 12: 63-87

Torelli, U. 1973. Notes ethnologiques sur les Banya-Mwenge du Toro. *Annali del Pontificale Museo* 37: 462-559

Tosh, J. 1970. The Northern Interlacustrine Region. In: R. Gray and D. Birmingham (eds.) *Pre-colonial African Trade: essays on trade in Central and Eastern Africa before 1900*. 102-118. London: Oxford University Press

Trigger, B. 1969. *Understanding Early Civilisations*. Cambridge: Cambridge University Press

Trigger, B. 2006. *A History of Archaeological Thought*. Cambridge: Cambridge University Press

Trowell, K. 1941. Some royal craftsmen of Buganda. *Uganda Journal* 8: 47-64

Trowell, M. and Wachsmann, K. 1953. *Tribal Crafts of Uganda.* London: Oxford University Press

Truffaut, E. 2008. Ferrum Noricum at the Hüttenberger Erzberg – specia ore or exceptional exertise? In: B. Cech (ed.) *The Production of Ferrum Noricum at the Hüttenberger Erzberg: the results of interdisciplinary research at Semlach/Eisner between 2003-2005.* 251-271 Vienna: OGA

Tylecote, R. 1962. *Metallurgy in Archaeology*. London: Edward Arnold

Tylecote, R. 1975. The origin of iron smelting in Africa. *West African Journal of Archaeology* 5: 1-9

Tylecote, R. 1987. *The Early History of Metallurgy in Europe.* London: Longman

Tylecote, R. 1992. *A History of Metallurgy*. London: Institute of Materials

Uzoigwe, G. 1972. Precolonial markets in Bunyoro-Kitara. *Comparative Studies in Society and History* 14: 422-455

Uzoigwe, G. 1976. Precolonial markets in Bunyoro-Kitara. In: B. Ogot (ed.) *Economic and Social History of East Africa.* 24-66. Nairobi: Kenya Literature Bureau

Uzoigwe, G. 1979. (ed.) *Anatomy of an African Kingdom: a history of Bunyoro-Kitara*. New York: Doubleday

Uzoigwe, G. 1982. *Uganda: the dilemma of nationhood.* New York: NOK Publishers

Valeton, I. 1994. Element concentration and formation of ore deposits by weathering. *Catena* 21: 99-129

van der Leeuw, E. and Torrence, R. 1989. (eds.) *What's New? A Closer Look at the Process of Innovation.* London: Unwin Hyman

van der Merwe, N. 1980. The Advent of Iron in Africa. In: T. Wertime and J. Mulhy (eds.) *The Coming of the Age of Iron.* 463-506. New Haven

van der Merwe, N. and Avery, D. 1987. Science and Magic in African Technology: Traditional Iron Smelting in Malawi. *Africa* 57: 143-172

van der Merwe, N. and Killick, D. 1979. Square: an iron smelting site near Phalaborwa. In: N. van der Merwe and T. Huffman (eds.) *Iron Age Studies in Southern Africa.* South African Archaeological Society Goodwin Series 3: 86-93

van Grunderbeek, M.-C. 1988. Essai d'étude typologique de céramique urewe dans la région des collines au Burundi et Rwanda. *Azania* 23: 11-55 van Grunderbeek, M.-C. 1992. Essai de delimitation chronologie de L'Age du Fer Ancien au Burundi, au Rwanda et dans la region des Grand Lacs. *Azania* 27: 53-80

van Grunderbeek, M-C., Roche, E. and Doutrelepont, H. 1982. Le Age du Fer Ancien au Rwanda et au Burundi, Archaeologie et Environment. *Journal des Africanistes* 52: 5-58

van Grunderbeek, M-C., Roche, E. and Doutrelepont, H. 1983. *Le Premier Age du Fer au Rwanda et au Burundi, Archaeologie et Environment.* Brussels: Institut National de Recherché Scientifique

van Grunderbeek, M-C., Roche, E. and Doutrelepont, H. 2001. Un Type de Font de Fer Associe a la Culture Urewe (Age de Fer Ancien) au Rwanda et au Burundi. *Mediterranean Archaeology* 14: 271-297

van Noten, F. 1972. *Les tombes du roi Cyirima Rujugira et de la reine-mère Nyirayuhi Kanjogera: Description archéologique*. Tervuren: Musée Royal de l'Afrique Centrale

van Noten, F. 1979. The Early Iron Age in the interlacustrine region: the diffusion of iron technology. *Azania* 14: 61-79

van Noten, F. 1983. (ed.) *Histoire Archeologique du Rwanda*. Tervuren: Musee Royal de l'Afrique Centrale

van Noten, F. 1985. Ancient and modern iron smelting in central Africa: Zaïre, Rwanda and Burundi. In: R. Haaland and P. Shinnie (eds.) *African Iron Working – ancient and traditional*. 102-120. Oxford: Oxford University Press

van Riet, L. 1952. The Pleistocene Geology and Archaeology of Uganda, Part II, Prehistory. *Geological Survey of Uganda Memoir* 6

Vansina, J. 1985. *Oral Tradition as History*. London: James Currey

Vansina, J. 1990. *Paths in the Rainforest: Towards a History of Political Tradition in Equatorial Africa.* London: James Currey

Vansina, J. 2004. *Antecedents to Modern Rwanda: the Nyiginya Kingdom.* Oxford: James Currey

Veldhuijzen, H. 2003. 'Slag_Fun'_ a new tool for archaeometallurgy: development of an analytical (P)ED-XRF method for iron-rich materials. *Papers from the Institute of Archaeology* 14: 102-118

Veldhuijzen, H. 2005. *Early Iron Production in the Levant: Smelting and Smithing at Early 1st Millenium BC Tell Hammeh, Jordan, and Tel Beth-Shemesh, Israel*. Unpublished PhD thesis. London: UCL

Veldhuijzen, H. and Rehren, Th. 2007. Slags and the city: early iron production at Tell Hammeh, Jordan, and Tel Beth-Shemesh, Israel. In: La Niece, S., Hook, D., Craddock, P. (eds.) *Metals and Mines: Studies in Archaeometallurgy.* 189-201. London: Archetype

Verein Deutscher Eisenhüttenleute (ed.) 1995. *Slag Atlas*. Düsseldorf: Verlag Stahleisen Gmbtt

Vignati-Pagis, E., 1995. *Du Fourneau a la Fosse: Changements Techniques dans la Métallurgie du Fer au Burundi au Cours des Duex Derniers Millenaires?* Unpublished PhD thesis. Paris: Université de Paris

Wagner, D. 1999. The earliest use of iron in China. In: S. Young, M. Pollard, P. Budd and R. Ixer (eds.) *Metals in Antiquity.* 1-9. Oxford: Archaeopress

Wainwright, G. 1954. The diffusion of "uma" as a name for iron. *Uganda Journal* 18: 113-136

Waldbaum, J. 1999. The coming of iron in the Eastern Mediterranean. Thirty years of archaeological and technological research. In: Pigott, V. (ed.) *The Archaeometallurgy of the Asian Old World*. 27-57. Pennsylvania: MASCA

Wayland, E. 1920. *Some facts and theories relating to the Geology of Uganda.* Uganda: Government Press

Wayland, E. 1934. Notes on the Biggo bya Mugenyi: some ancient earthworks in northern Buddu. *Uganda Journal* 2: 21-34

Webster, J., Ogot, B. and Chrétien, J.-P. 1992. The Great Lakes Region, 1500-1800. In: B. Ogot (ed.) *UNESCO General History of Africa (Vol. V) Africa from the Sixteenth to the Eighteenth century*. 776-827. London: Heinemann

Wiessner, P. 1983. Style and social information in Kalahari San projectile points. *American Antiquity* 48: 253-276

Wiessner, P. 1985. Style or isochrestic variation? A reply to Sackett. *American Antiquity* 50: 160-166

Willis, J. 1997. Clan and history in western Uganda: a new perspective on the origins of pastoral dominance. *The International Journal of African Historical Studies* 30: 583-600

Wilson, S. 1997. Data compilation for USGS reference material BHVO-2, Hawaiian Basalt, *U.S. Geological Survey Open-File Report*

Woodhouse, J. 1998. Iron in Africa: metal from nowhere. In: G. Connah (ed.) *Transformations in Africa: essays on Africa's history.* 160-185. London: Leicester University Press

Wrigley, C. 1958. Some thoughts on the Bacwezi. *Uganda Journal* 22: 11-17

Wrigley, C. 1996. *Kingship and State: the Buganda dynasty*. Cambridge: Cambridge University Press

Wyckaert, P. 1914. Forgerons païens et forgerons chrétiens au Tanganyika. *Anthropos* 9: 367-380

Wylie, A. 2002. The typology debate. In: A. Wylie (ed.) *Thinking from Things: essays in the philosophy of archaeology*. Berkeley: University of California Press

Appendix A

Kooki survey report and Kiwesi site report

The survey zone in Rakai district covered an area of approximately 20km by 30km, encompassing all or part of the sub-counties of Kifamba, Byakabanda, Lwanda, Dwaniro and Kagamba within the county of Kooki. Survey spanned from Kinyabuddu in the west to Lwanda in the east, and from Lwendaula in the north to Kifamba in the south (using 1:50,000 maps from the Uganda Department of Lands and Surveys, numbered 87/4 and 87/2). The environment of the central area of this survey zone was dominated by Lake Kijanebalola, with associated sandy lakeshores and low-lying marshland. To the north of the lake, the setting quickly became much more dramatic, with steep hillsides culminating in large, flat, often bare, plains on top. Towards the south a similar pattern occurred, with rocky outcrops and high, large hills. The most southerly extent of the survey zone was demarcated by a steep drop-off running east to west, linking the towns of Kalungi and Kifamba.

An identical survey approach was applied here as was in Kyenjojo. Within Kooki, a further 44 sites were located (Figure A.1), most of which were characterised by large slag blocks, whilst others comprised smaller scatters of slag fragments. All sites that were located in this area were provisionally dated to the LIA by associated ceramic assemblages (see also Appendix C). Two sites were found that contained traces of preserved furnace bases; one of these (Kiwesi) was notable for the presence of many small pit features (remaining as small hollows in compounds and plantations), which were later found to be related to smelting activity (see below), as well as a well-preserved furnace base. Similar hollows had been noted in this region throughout the survey, although it was not until *after* the excavation that it was supposed that they might generally be associated with iron production events. As the prior assumption had been that they were associated with modern household activity, these hollows had not been recorded on the survey sheets but might be a valuable tool for recognising iron production sites in the future, within this region at least. These features were not encountered during the survey in Mwenge or Masindi.

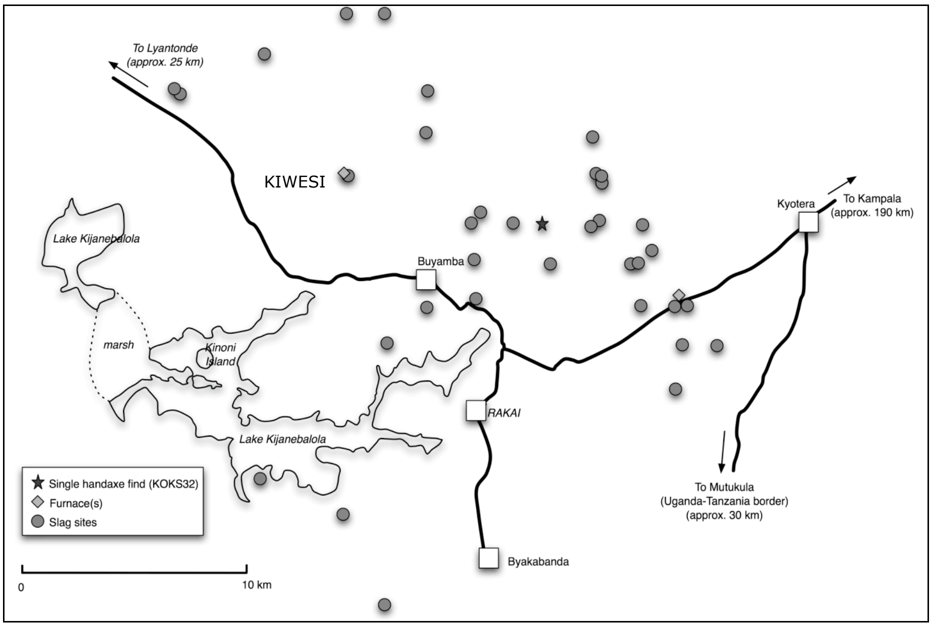


Figure A.1 Sites found during the 2007 fieldwork in Kooki, with Kiwesi indicated

One site, Kiwesi, was selected for excavation based on the density and apparent preservation of the archaeological remains, which included, above all, the presence of a well-preserved furnace base. Iron production remains extended throughout the modern village, and these were mapped and recorded. Our attention was drawn to a number of hollows by inhabitants who associated them with smelting; as a result of this, these hollows were also planned (*cf.* Figure A.2).

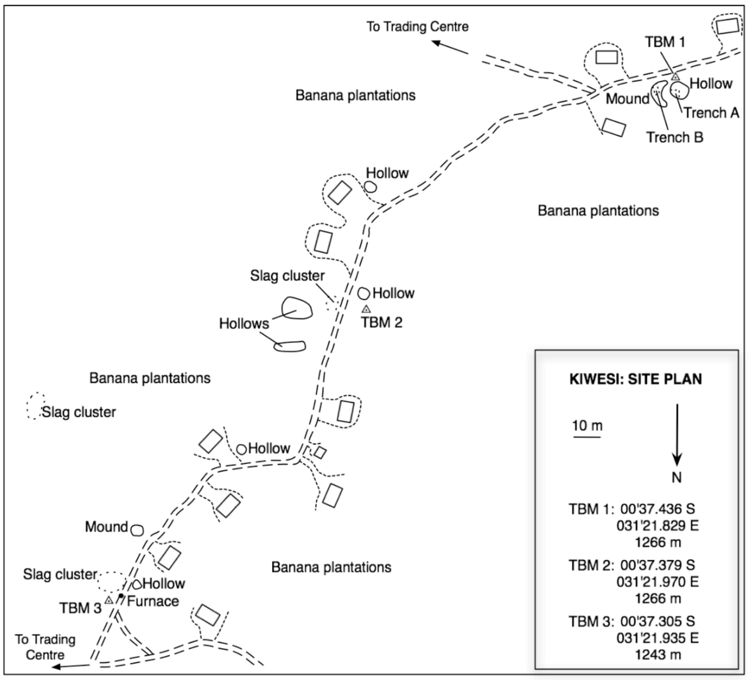


Figure A.2 Site plan of Kiwesi

Several features were chosen for excavation. The furnace base was excavated, one of the hollows was quarter-sectioned, and a cross-section was put through the mound shown in Figure A.2. In addition to this, fifteen blocks of slag were fully recorded, and samples were taken from them for further analysis.

Through excavation, the furnace pit was revealed to be over one metre in depth (Figure A.3). At a depth of approximately 30 to 40cm, the upper, somewhat mixed fills came down onto a large furnace slag block that was approximately 60cm in diameter and 20cm deep (Figure A.4). On removal, it was found to be bowl-like in shape (reminiscent of some of the concave slag blocks from Mirongo Group 2), and covered in medium to large papyrus impressions, especially on its upper surface (Figure A.5). It weighed 71kg.

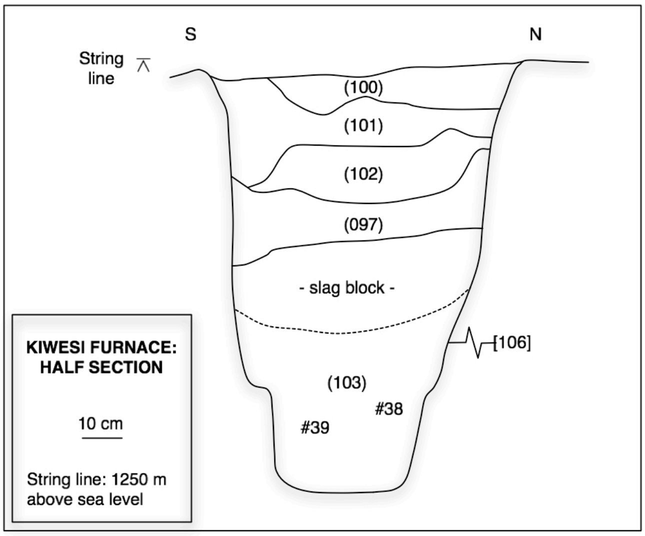


Figure A.3 Composite section drawing of fully excavated furnace at Kiwesi, Kooki

Figure A.4 Furnace slag in-situ, Kiwesi

Figure A.5 Furnace slag, Kiwesi, half sectioned

Once it was fully excavated, the very bottom of the furnace revealed a 'stepped' profile (*cf.* Figure A.3 and A.6), which raised the possibility that this was once a ritual pit into which medicines were put to ease the progression of a smelt. However, there was no notable variation in fill between the contents of this region of the furnace pit and the rest of context (103): this lower furnace fill was a homogeneous dark loose silt, friable and very charcoal-rich, with frequent occurrences of well-preserved charred papyrus. A charcoal sample (#38) taken from the middle of this context (*cf.* Figure A.3) generated a radiocarbon date of 122 ±29 BP, which calibrates to 1697-1940 cal. AD with a 95.4% probability (OxCal 4.1; IntCal09; Bronk Ramsey 2009).

Figure A.6 Furnace at Kiwesi, fully excavated

Concurrent excavations were undertaken at two additional features, a small mound and a small hollow in the south of the village, approximately 200m to the southwest of the excavated furnace. The mound was found to comprise a built-up pile of (generally unbroken) slag blocks arranged in a semi-circle (Figure A.7). Beyond this was a shallow hollow (Figure A.8), with several thin lenses of deposits, some of which indicated burning. There was a large volume of tuyères and slag fragments recovered from both of these features. No furnace remains were discovered in the vicinity, however these features were located in banana plantations with thick ground coverage of plant material (banana leaves placed there intentionally to protect the growing crops). The purpose and formation of these features could not be ascertained in the time that we were there, but the regular occurrence of these features in the area suggests that they may provide a valuable opportunity to examine the organisation of local iron production in the future.

Figure A.7 Mound of slag blocks, Kiwesi, mid-excavation

Figure A.8 Hollow, Kiwesi, mid-excavation

Along with the slag block removed from the excavated furnace, fourteen further slag blocks were examined from this site, several excavated from the features described above, and several from a cluster of slag blocks located close to the furnace remains (*cf.* Figure A.2). The average weight of a single slag block was approximately 45kg. All of the sampled slag blocks were relatively complete, all were similar in size and shape to that excavated from the furnace, and all bore frequent papyrus impressions. Furthermore, on sectioning and sampling, all were found to be very brittle.

Due to time constraints only a cursory compositional analysis (PED-XRF) of the samples taken from these remains was undertaken, including both the slag samples described above as well as two ore samples (one taken from the furnace (Figure A.9) and one that was found attached to a slag block), in conjunction with several ceramic samples: a furnace wall and tuyère sample (Figure A.10), and two domestic pottery samples.

Figure A.9 Sample of unreduced ore excavated from furnace, Kiwesi. Specimen size approximately 2cm^3

Figure A.10 Fragments of tuyère excavated from pit fill (098) of the hollow, Kiwesi. Coarse grog tempering is visible in the sample on the bottom row, second from the left

KIWESI (KWI)	Major and minor compounds													
	Na_2O wt%	MgO wt%	Al_2O_3 wt%	*SiO_2 wt%*	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%
				original	adjusted									
Cluster 1 Slag 1 M	0.24	0.39	10.47	*31.85*	31.85	1.52	0.08	3.27	3.58	0.47	0.01	0.05	0.08	47.62
Cluster 1 Slag 2 M	0.34	0.37	10.00	*31.32*	31.00	2.25	0.08	3.30	4.94	0.59	0.00	0.06	0.14	46.25
Cluster 1 Slag 3 M	0.25	0.32	11.26	*24.14*	20.76	2.28	0.09	2.79	2.82	0.45	0.03	0.13	0.10	55.17
Cluster 1 Slag 5 T	0.32	0.49	12.22	*32.87*	32.87	2.12	0.08	4.10	5.17	0.62	0.01	0.11	0.11	41.51
Cluster 2 Slag 2 B	0.34	0.32	9.35	*28.92*	27.48	1.51	0.12	3.11	2.51	0.48	0.01	0.09	0.08	52.94
Cluster 2 Slag 2 M	0.16	0.24	11.47	*28.09*	26.41	1.32	0.10	3.43	1.86	0.46	0.03	0.15	0.06	52.45
Cluster 2 Slag 2 T	0.34	0.21	10.45	*28.88*	27.44	1.50	0.10	3.56	2.18	0.45	0.02	0.10	0.07	51.92
Cluster 2 Slag 3 Dense	0.19	0.27	9.83	*28.50*	28.07	1.71	0.13	3.83	2.69	0.45	0.02	0.09	0.07	51.93
Cluster 2 Slag 5 B	0.25	0.52	9.14	*28.73*	27.29	1.80	0.11	3.17	5.24	0.46	0.01	0.07	0.15	50.10
Cluster 2 Slag 6 M	0.29	0.31	8.87	*27.36*	25.17	2.64	0.11	3.25	3.55	0.45	0.00	0.04	0.11	52.84
Furnace Slag Dense	0.13	0.20	8.44	*24.48*	21.55	1.80	0.11	2.15	2.57	0.38	0.01	0.13	0.11	59.25
Ore (from furnace)	/	/	8.35	*5.88*	4.12	0.80	0.04	0.14	0.04	0.38	0.02	0.20	0.05	83.44
Cluster 1 Slag 6 Ore	0.10	/	8.19	*30.07*	29.17	1.30	0.11	2.16	0.13	0.31	/	0.02	0.03	57.42
Pot A	0.33	0.60	21.46	*68.09*	68.09	0.14	0.06	2.51	0.81	0.95	0.00	0.02	0.02	4.79
Pot B	0.17	0.46	19.75	*70.61*	70.61	0.05	0.03	3.20	0.69	0.91	/	0.02	0.04	3.83
Tuyère	0.28	0.40	22.81	*68.19*	68.19	0.04	0.02	2.35	0.32	0.92	0.01	0.02	0.03	4.36
Furnace Wall	0.34	0.30	20.83	*65.66*	65.66	0.13	0.07	1.66	0.50	1.57	0.01	0.03	0.31	8.33

KIWESI (KWI)	Trace compounds												
	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	Rb_2O ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Cluster 1 Slag 1 M	581	/	49	64	37	310	172	338	416	696	769	280	106.50
Cluster 1 Slag 2 M	458	/	49	45	27	504	99	415	642	452	509	165	107.72
Cluster 1 Slag 3 M	526	/	28	45	6	162	33	214	286	106	142	22	107.54
Cluster 1 Slag 5 T	483	/	38	85	63	487	64	326	626	219	304	22	106.92
Cluster 2 Slag 2 B	550	/	45	147	/	224	97	295	362	197	247	32	109.82
Cluster 2 Slag 2 M	443	/	24	75	31	169	84	248	306	213	278	79	108.71
Cluster 2 Slag 2 T	453	/	31	61	31	213	108	293	367	238	345	80	108.33
Cluster 2 Slag 3 Dense	419	/	54	70	35	259	146	284	288	604	607	170	110.45
Cluster 2 Slag 5 B	499	/	36	39	22	499	52	303	737	124	288	23	108.06
Cluster 2 Slag 6 M	518	/	20	35	21	273	33	246	356	119	163	33	110.27
Furnace Slag Dense	648	/	61	225	/	213	48	237	379	159	240	64	108.55
Ore (from furnace)	729	247	84	721	/	/	174	173	7	1758	1903	823	97.58
Cluster 1 Slag 6 Ore	567	/	72	246	/	/	36	201	386	47	127	0	100.61
Pot A	69	/	/	58	167	176	/	713	604	115	177	92	95.71
Pot B	73	/	/	484	170	159	/	627	566	136	227	146	100.60
Tuyère	74	/	/	89	194	85	/	758	552	259	279	175	101.50
Furnace Wall	144	/	/	110	136	107	/	1021	504	168	343	112	93.11

Table A.1 PED-XRF compositional data for all samples from Kiwesi, normalised to 100%. All values are the average of three analyses of each sample. 'Analytical total' shows the analytical total prior to normalisation

A number of points can be made just from a brief examination of the PED-XRF data. Firstly, the high alumina to silica ratio in the ore sample from the furnace, and the high alumina levels in the slag suggest that these smelts would have had to have operated at a relatively high temperature. This may have resulted in a high fuel consumption, and consequent high fuel ash contribution, potentially accounting for the raised levels of lime and potash in the slag samples. It is possible that the raised phosphate levels are due at least in part to contributions from the ore.

The manganese oxide levels in these samples are considerably lower than the average manganese oxide composition of the Mwenge samples. However, iron oxide contents are also relatively low; there is not much unreduced iron remaining in the slag. Levels of barium oxide, and the rare earth compounds are also in general lower than the samples from Mwenge.

The bulk compositional analysis also shows that the technical ceramics and the domestic pottery are very similar, which presumably indicates that comparable approaches to clay procurement and tempering were applied in each case. Still, these ceramics would have been highly refractory, and able to withstand the posited high temperatures of these smelting episodes.

In isolation, and with little time to devote to these samples, there is only a limited amount that can be said about the technology in operation at this site. However, it is feasible to suggest that an efficient and effective smelting operation was in place, considering the density of remains at the site and the low level of compositional variation present from slag block to slag block. Depending on the time frame that these furnaces were operating within, the smelters working at this site may have fed markets responding to Ganda or Nyoro demands for iron, or both.

The families living in Kiwesi now, who say their ancestors smelted on this land, associate themselves with a Nyoro heritage and say their families only moved to Kooki in the eighteenth century (see Appendix D). If the furnace and slag blocks excavated from this site were remains associated with these families it is interesting that the style of smelting (at least, what can be seen with such little investigation) bears no resemblance to one yet excavated further to the west; the most immediate difference being the depth and size of the furnace pit with the potential use of a ritual pit at the bottom. As the historical records suggest strong links between the iron production technologies in this part of Uganda, those further west in Mwenge, and those to the north in Buganda, it will be interesting to see if future archaeometallurgical research in the area can shed light on the relationships between smelters in these regions.

Appendix B

Masindi survey report and Kisengya site report

The survey zone in Masindi district covered an area of approximately 30km by 30km, encompassing all or part of the sub-counties of Budongo, Bwijanga, Karujubu, Nyangahya and Miirya within the counties of Bujenje and Buruli. Survey spanned from Katugo in the west to Kigulya in the east, and from Kigumba in the north to Isimba in the south (using 1:50,000 maps from the Uganda Department of Lands and Surveys, numbered 39/3 and 38/4). Dense, protected forest reserves in the northwest (Budongo and Masaba) and marshy areas to the southeast restricted the survey, but the major problem encountered were the prolific sugar cane plantations, mainly in the centre and to the west which proved impossible to survey. Many areas no longer cropped for sugar cane had been so in the past, with subsequent sub-surface disturbance caused by the deep-furrowing tractors employed in this farming method. Nevertheless, this survey zone had the least imposing landscape, with gently rolling hills that didn't prove too much of an obstacle to either vehicles or walking survey.

During this survey, 59 archaeological sites were located, mostly characterised by scatters of slag fragments and pottery, with occasional furnace bases and a single iron-ore mining pit (Figure B.1).

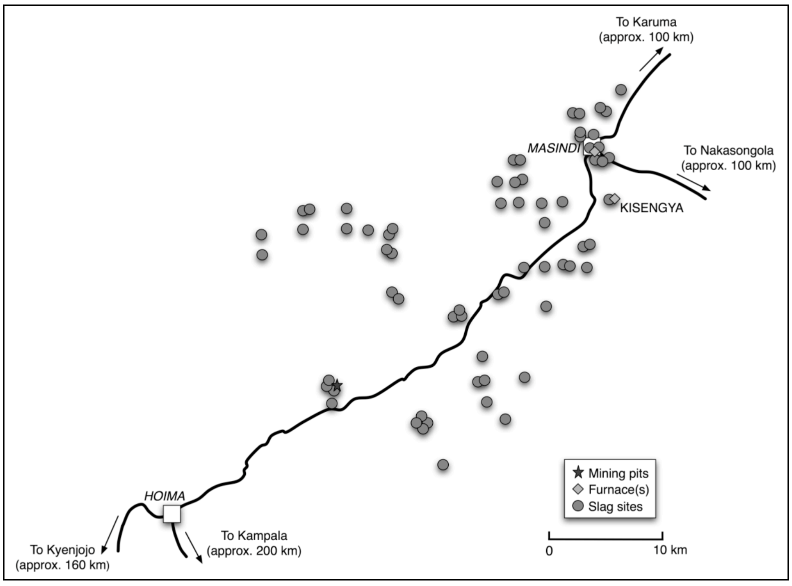


Figure B.1 Sites found during the 2007 fieldwork in Masindi

Again, most sites were provisionally dated to the LIA, due to the presence of carved wooden roulette and knotted strip roulette pottery (see Appendix C). The greatest concentration of sites appeared to cluster in the northeastern section of the survey zone. However, this may be due to the fact that archaeological sites towards the south and west of the survey area might have been hidden within the prolific sugar cane plantations there.

Iron production remains at one village, Kisengya (KSG), were selected for excavation, based on the amount of iron production remains in the vicinity and the site's accessibility. Two furnace bases were excavated (KSG2 and KSG3), and a single 2m^2 test pit was also excavated revealing an unstratified dumping area of slag blocks in a compound floor (KSG1); all of these were situated in different areas of the village (Figure B.2). Nine large slag blocks were recorded from Kisengya 1, of which six were sampled, but no further excavations were carried out at this site (Figure B.3).

Figure B.2 The three areas of excavation in Kisengya. Each of the sites is separated from the other by approximately 0.8km. The yellow line to the left of the image is the main Masindi-Hoima road; Ihungu marks the position of the sub-county headquarters. North is towards the top of the image. Image taken from Google Earth

Figure B.3 Fully excavated test pit at KSG1

The first furnace to be excavated was at Kisengya 2, which was located towards the top of a steep ridge (marked Nyakarunya on map 39/3) to the south of the Ihungu-Kijunjubwa road (Figure B.4). The vegetation was very dense, but we were led to an area where there was a concentration of small slag fragments, and on closer inspection furnace remains were faintly visible (Figure B.5).

Figure B.4 Ridgetop at Kisengya 2, from hill Nyakarunya looking east towards hill Nyabetereka

Figure B.5 Furnace remains at Kisengya 2 prior to clearance of vegetation. Furnace is situated under small bush in foreground

These furnace remains were excavated to reveal a circular furnace pit around 50cm in diameter, with vertical sides to about 45cm deep (although this may have been as much as 60cm deep originally, as we arrived at the site to find that the landowner had dug at the furnace overnight, believing there were coins buried there). The furnace wall was thickly lined with about 3cm of clay, which was baked hard; the base was not lined, and the dark brown, charcoal-rich, friable furnace fill (110) came down directly onto orange, stony natural (*cf.* Figure B.6). 13kg of slag fragments were recovered from the furnace fill, but no coherent slag block. One of these fragments plus a nearby slag block were sampled for further analysis. A charcoal sample (#40) was taken from the bottom of context 110 (*cf.* Figure B.7) and generated a radiocarbon date of 154 ±25 BP, which calibrates to 1684-1929 cal. AD with a 95.4% probability (OxCal 4.1; IntCal09; Bronk Ramsey 2009).

Figure B.6 Fully excavated furnace at Kisengya 2

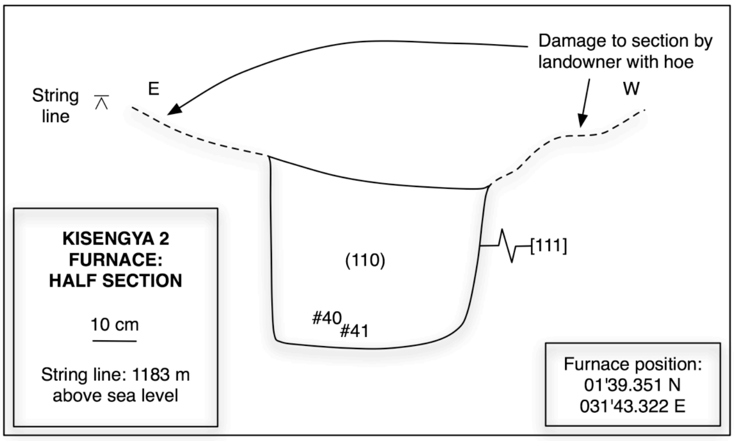


Figure B.7 Excavated furnace at Kisengya 2

A second furnace was found next to a narrow pathway at Kisengya 3, less than a kilometre to the north of Kisengya 2 (Figure B.8; *cf.* Figure B.2). On excavation, a surprising discovery was the pronounced bowl shape of the furnace pit, with distinct undercutting, suggestive of a lipped or lidded furnace (Figures B.9 and B.10). Immediately this called to mind Roscoe's descriptions of smelting in Hoima (*cf.* Roscoe 1923: 220). There were no tuyère ports apparent as might be expected, although these may originally have been above the level of the surviving furnace superstructure.

Figure B.8 Furnace at Kisengya 3, prior to excavation (trowel is pointing north)

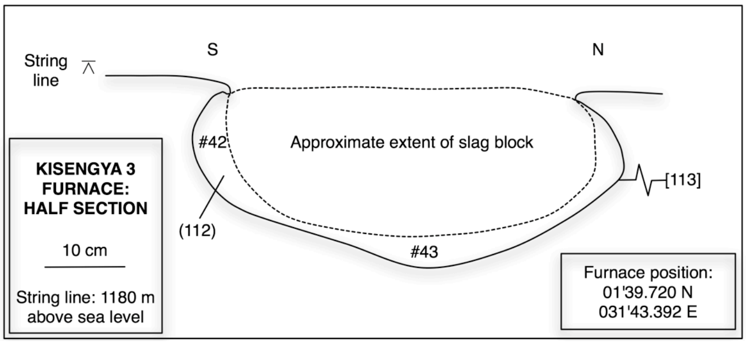


Figure B.9 Furnace at Kisengya 3, prior to excavation

Figure B.10 Fully excavated furnace at Kisengya 3, looking south

Two slag blocks completely filled the furnace structure, the upper one being visible in Figure B.8. The lower furnace block (the bottom of which is seen in Figure B.11) clearly mirrored the shape of the furnace base. Both furnace slags weighed approximately 30kg. A nearby slag cluster contained blocks that were very similar in dimensions and weight. Four of these were recorded in detail; two of these were sampled for further analysis.

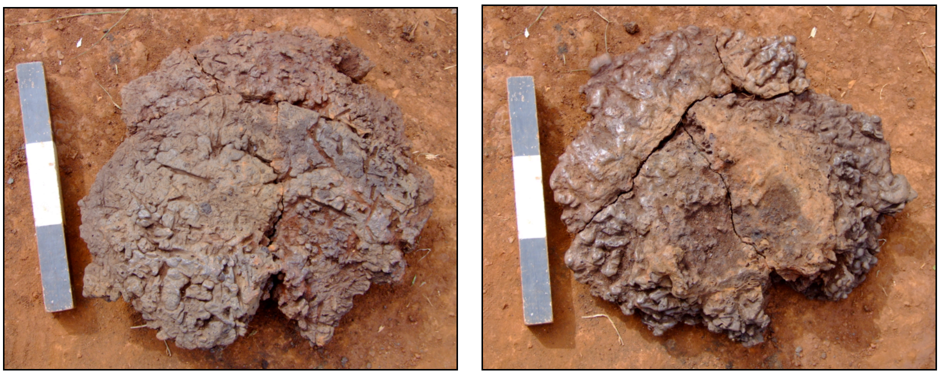


Figure B.11 Lower slag block recovered from furnace at Kisengya 3 (left = bottom; right = top)

In total, twelve slag blocks from Kisengya were sampled from, which were analysed using PED-XRF (Table B.1).

	Major and minor compounds													
KISENGYA	Na_2O	MgO	Al_2O_3	SiO_2	*SiO_2*	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO
(KSG)	wt%	wt%	wt%	wt%	*wt%*	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
				original	*adjusted*									
KSG (107) Slag 1 M	0.24	0.44	7.53	26.97	*24.82*	0.68	0.08	2.32	4.15	0.21	/	0.02	4.58	52.27
KSG (107) Slag 2 M	0.15	0.75	7.76	21.15	*17.55*	0.64	0.07	2.32	5.30	0.17	/	0.02	4.32	56.99
KSG (107) Slag 4 M	0.25	0.53	8.38	27.71	*25.77*	0.79	0.08	2.11	4.36	0.37	0.00	0.03	2.29	52.56
KSG (109) Slag 2 B	0.21	0.59	7.17	22.28	*18.94*	0.67	0.08	2.10	4.04	0.25	0.01	0.02	1.64	60.66
KSG (109) Slag 4 M	0.18	0.39	5.33	22.49	*19.12*	0.92	0.07	1.48	2.97	0.13	/	0.02	3.19	62.38
KSG (109) Slag 5 B	0.25	0.45	7.70	30.59	*29.98*	0.76	0.07	1.79	3.35	0.19	/	0.02	4.06	50.00
KSG2 (110)	0.25	0.77	7.78	26.00	*23.40*	1.93	0.06	0.76	6.53	0.45	0.01	0.03	1.46	53.47
KSG2 Cluster 1 Slag 1 B	0.23	1.19	7.43	28.55	*26.84*	2.21	0.06	0.83	8.69	0.45	0.00	0.03	1.00	48.88
KSG3 Cluster 1 Slag 1 M	0.31	0.51	11.12	25.72	*23.15*	2.13	0.09	2.85	4.05	≤0.05	/	0.04	6.47	45.81
KSG3 Cluster 1 Slag 3 M	0.16	0.71	7.11	16.76	*13.24*	1.17	0.06	1.97	4.30	0.23	0.00	0.02	1.32	65.92
KSG3 Furnace Slag 1 M	0.18	0.51	7.99	25.05	*22.17*	1.21	0.09	2.20	4.97	0.23	/	0.02	3.53	53.50
KSG3 Furnace Slag 1 B	0.13	0.63	8.07	24.93	*22.06*	1.31	0.09	2.20	5.47	0.22	/	0.03	3.59	52.82
KSG3 Furnace Slag 1 T	0.23	0.47	9.78	20.36	*16.74*	0.93	0.07	1.50	3.18	0.25	0.01	0.05	3.08	59.72
KSG3 Furnace Slag 2 B	0.19	0.46	7.63	21.47	*17.92*	1.57	0.08	2.20	3.08	0.15	/	0.03	4.34	57.77
KSGJ Pot A	0.25	0.65	20.04	63.32	*63.32*	0.05	0.04	1.81	1.06	1.21	0.01	0.01	0.03	11.29
KSG Pot B	0.16	0.51	18.48	71.17	*71.17*	0.19	0.04	1.74	1.14	1.06	0.00	0.02	0.03	5.24
KSG2 Furnace Wall	0.22	0.17	10.10	84.35	*84.35*	0.01	0.04	0.29	0.12	1.14	/	0.01	0.03	3.39
KSG2 Tuyère	0.14	0.44	20.17	71.31	*71.31*	0.04	0.06	0.88	0.37	1.35	0.01	0.02	0.02	4.97
KSG3 Furnace Wall	0.20	0.39	14.08	78.29	*78.29*	0.04	0.04	0.80	0.35	1.01	/	0.01	0.04	4.59

	Trace compounds										
KISENGYA	Co_3O_4	CuO	Rb_2O	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
(KSG)	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
KSG (107) Slag 1 M	/	36	/	255	50	307	3645	117	412	269	109.30
KSG (107) Slag 2 M	/	26	/	350	42	233	2516	107	357	140	114.93
KSG (107) Slag 4 M	292	47	/	265	55	373	3061	294	631	215	107.50
KSG (109) Slag 2 B	500	29	/	222	51	241	1197	132	287	/	115.51
KSG (109) Slag 4 M	274	39	/	182	48	177	3221	42	273	169	112.67
KSG (109) Slag 5 B	/	33	/	235	54	324	5847	147	622	355	105.83
KSG2 (110)	471	27	/	407	63	444	3080	94	250	252	105.93
KSG2 Cluster 1 Slag 1 B	583	29	/	527	57	420	2205	143	229	244	106.12
KSG3 Cluster 1 Slag 1 M	/	47	/	807	44	272	6280	215	693	392	111.73
KSG3 Cluster 1 Slag 3 M	594	40	/	252	36	212	1367	31	157	/	115.37
KSG3 Furnace Slag 1 M	139	33	/	389	57	348	3385	116	524	280	110.92
KSG3 Furnace Slag 1 B	133	29	/	442	57	364	3311	119	498	212	110.76
KSG3 Furnace Slag 1 T	258	53	/	223	43	305	2184	76	379	≤232	109.36
KSG3 Furnace Slag 2 B	/	63	/	169	46	276	9049	/	348	491	114.71
KSG Pot A	134	42	70	139	/	862	670	126	210	105	92.42
KSG Pot B	70	41	52	156	/	852	559	143	221	140	97.28
KSG2 Furnace Wall	60	14	24	17	/	852	114	38	69	92	100.00
KSG2 Tuyère	89	59	60	62	/	935	439	159	276	147	96.36
KSG3 Furnace Wall	78	28	57	38	/	734	255	107	161	124	97.54

Table B.1 PED-XRF compositional data for all samples from Kisengya, normalised to 100%. All values are the average of three analyses of each sample. 'Analytical total' shows the analytical total prior to normalisation

There were several interesting points raised through these analyses. Lime levels were particularly and consistently high (up to around 8wt%), indicating either a large contribution of fuel ash to the melt or a very lime-*rich* fuel (none of the analysed ceramics were very calcareous), or the separate addition of a different lime-rich flux.

Furthermore, manganese oxide levels were highly variable, ranging from 1wt% to over 6wt% in samples from two slag blocks found close to the Kisengya 3 furnace (correlating, as would be expected, with variations in iron oxide content). This variation allowed a superficial assessment of some potential patterns in the data, particularly a potential association between manganese oxide and barium, neodymium, lanthanum and cerium oxides: a pattern of chemical relationships seen also in the high manganese-slags in Mwenge.

The samples that seemed most anomalous were those from Kisengya 2. These samples showed the highest lime contents (as well as magnesia, phosphate, titania and cobalt oxide), and were among those with the lowest manganese oxide levels (and potash). Due to the nature of how lime behaves with a smelt, these slag blocks also had quite low levels of iron oxide; it was samples with low levels of both lime and manganese oxide that showed the highest iron oxide (Figure B.12).

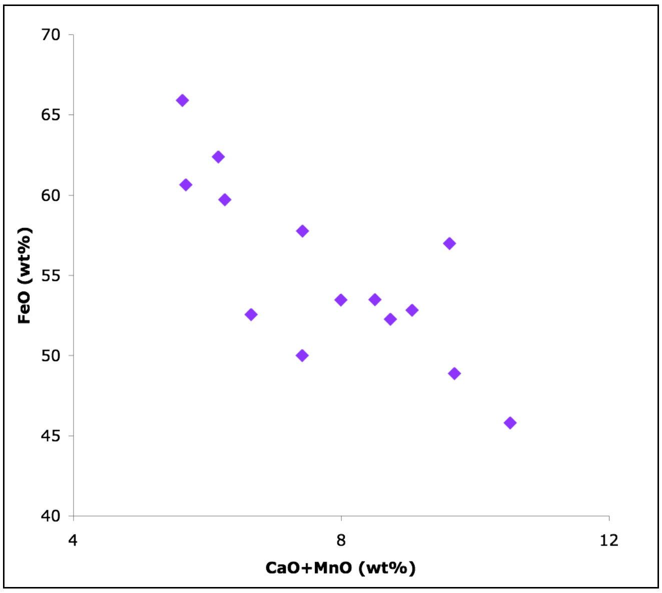


Figure B.12 Correlations between iron oxide and lime and manganese oxide levels in the slag samples from Kisengya

The furnace wall samples from both of the furnaces were very similar, and neither seemed to have been much contaminated by the melt. Together with the tuyère sample from Kisanja 2, all the technical ceramics samples appeared very similar except in silica content; it is feasible that the furnace wall samples (which contained around 80 to 85wt% silica) may have been more heavily tempered with silica. Conversely, this may reflect a choice of quartz-rich termite clay for this purpose, a strategy that has been documented elsewhere for the preparation of furnace clays (*cf.* Brown 1995: 25). If the tuyère sample is a true representation of a moderately tempered technical ceramic typical of Kisengya, then the clay used can be considered to be fairly refractory with alumina contents of around 20wt%.

Although there is variation within all three groups of slag, within each group there are also some broad similarities that serve to distinguish them from the other groups. However, the samples from Kisengya 1 and 3 are much more similar to each other than the samples from Kisengya 2. This correlates nicely with the consistency in slag morphology between these sites (compare Figures B.3 and B.11), which may possibly relate to a similar (though not identical) smelting procedure being carried out at these two sites. Furthermore, these sites are both situated very close to water sources on relatively low land. Conversely, the slag remains, furnace remains and bulk chemical analysis of Kisengya 2 – situated towards the top of a high ridge – suggest the implementation of what may have been a different technology from those working (although not necessarily concurrently) in the valley below.

Again, these initial findings from Kisengya, although not pursued very far, have indicated the very high likelihood of smelting variation being encountered within a very small locale (although, once again, no temporal relationships between these sites can be resolved at this time). Possible parallels between these technologies, those seen in Mwenge (200km to the southwest) and the ethnohistoric record for this region are highly intriguing. Clearly there is a lot more to be learnt about the organisation of iron production technologies across the whole of western Uganda.

Appendix C

Kyenjojo Survey

KYS1	030°31.547 E
Butiti Sub-County HQ (“tiny beads”)	00°38.146 N
17 July 2007	1470m

Smelting site, within compound of sub-county headquarters, indicated by remains of furnace wall preserved in road, and medium-density scatter of slag and pottery (TGR). Site is situated on gentle west-facing slope of small hill; red, compacted soils; highly disturbed by road and agriculture; site covers approx. 30m^2; low visibility of remains due to high levels of vegetation.

KYS2	030°38.633 E
Nyantungo Sub-County HQ	00°35.565 N
18 July 2007	1393m

Low-density scatter of slag and pottery (KPR, incised lines) in fields and compounds surrounding sub-county headquarters. High levels of general disturbance due to agricultural activity and road construction.

KYS3	030°31.465 E
Birenge	00°38.791 N
18 July 2007	1447m

Smelting site indicated by large number of medium-sized slag blocks. Close to Butiti trading centre. Main concentration of slag in compound of Businge Perusi, where slag is also used within the house foundations. High levels of agricultural disturbance.

KYS4	030°31.390 E
Birenge	00°39.175 N
18 July 2007	1452m

Mining site, consisting of approximately 50 ‘enambo’ or iron-ore mining pits scattered across steep, north-facing, wooded hillside. Pits measure about 1m in diameter, and about 10-20m deep. Several have been filled in to prevent animals falling in.

KYS5	030°31.681 E
Mukunyu (nr. Kisururumi village) (“wild fig tree”)	00°39.462 N
18 July 2007	1460m

Mining site, on southeast hillside facing KYS4, close to main Kyenjojo-Fort Portal road. Many pits filled in, and fewer in number than KYS4. Some shallower pits with larger openings, and many run horizontally at bottom. Said to run underground to reach opposite hill.

KYS6	030°30.990 E
Nyabubale	00°38.013 N
18 July 2007	1469m

Medium-density slag scatter, consisting primarily of slags collected during field clearance. Some pottery (TGR). Local man remembers smelting in the area. Site situated on gentle, south-facing slope, in cultivated compound, on red soils.

KYS7	030°30.656 E
Kanyankoko (“a grass”)	00°37.712 N
19 July 2007	1485m

Mining site, on open south-facing hillside, that’s pockmarked with the remains of mining pits. Most have now been filled in for reasons of safety, but we saw one that had remained open. Similar to other enambo: circular and 1m in diameter with vertical sides.

KYS8	030°30.956 E
Kyangabukama (nr. Mirongo trading centre) (“child of kingdom”)	00°37.152 N
19 July 2007	1480m

Medium-density slag scatters in cultivated areas of compounds and pathways on southwest-facing slope of Kyangabukama. Also a number of furnace bases in main pathway [030°30.863 E; 00°37.174 N; 1462m], approximately 1m in diameter. Some pottery (KPR).

KYS9	030°30.220 E
Mirongo 1 (“a tree for charcoal”)	00°37.092 N
19 July 2007	1517m

Low-density scatter of slag in overgrown banana plantation, on slight north-facing slope, and dark-grey humic soils. The landowner remembers the exact place where iron was smelted up to 100 years ago by his grandfather, now highly disturbed by cultivation.

KYS10	030°31.323 E
Kyakikoto (“place of Kikoto”)	00°36.241 N
19 July 2007	1431m

Small furnace base (c. 35/40cm in diameter) on main Mirongo-Nyantungo road, and three small clusters of slag along road (which may indicate further furnaces). A smelter called Kikoto used to smelt here (he died last year). It was suggested to us that slag and furnaces would remain undisturbed in the neighbouring fields, but vegetation cover was very thick. Present landowner is called Antonio Mutabazi.

KYS11	030°32.764 E
Kihora (Mbale, "a red cow")	00°35.767 N
20 July 2007	1418m

Moderate-density slag scatter in the compound of the LC1, who says smithing was practiced there up to 50 years ago, but smelting happened before she was born. Apparently two types of ore were used. Site situated on northeast-facing, steep-sided slope on cultivated land with reddish grey soils. The slope leads down to a stream at the bottom of the compound fields. Many slags apparently buried about 2.5 feet deep due to the erosion on the slope. Some pottery (KPR).

KYS12	030°32.664 E
Kihora (Mbale)	00°35.737 N
20 July 2007	1452m

High-density slag scatter in road running along ridge-top, in red, compacted soils. Slag and pottery occurring in an area of about $10m^2$. According to local LC1, this was a 'workshop' area for smelting activity.

KYS13	030°33.278 E
Kisarwampunu ("wild pigs")	00°33.803 N
20 July 2007	1446m

Presumed smelting site, indicated by the presence of a large number of medium slag blocks in the compound of the LC1 of Kyanyama, who believes smelting was taking place here about 1000 (?) years ago. The site is situated in hilly, agricultural land, with dark, ashy soils, on a west-facing slope.

KYS14	030°33.391 E
Kyanyama	00°33.848 N
20 July 2007	1366m

Low-density scatter of slag blocks on an open, southwest-facing, steep hillside used as pasture for cattle.

KYS15	030°33.776 E
Kirongo	00°35.983 N
20 July 2007	1446m

Smelting site indicated by furnace base in compound and slag blocks in nearby fields; medium-density scatter of pottery (TGR, KPR) and slag. Site is situated in the swept compound and in the surrounding agricultural fields (banana and cassava) on a south-facing slope coming down from Kirongo Hill; reddish-black ashy soils.

KYS16	030°33.702 E
Kirongo	00°35.936 N
20 July 2007	1450m

Seven mining pits, on south/southwest-facing slope of hill covered with scrub – most have now been filled in. One pit is about 20m long, oval in shape, and very deep (difficult to estimate, very overgrown).

KYS17	030°35.869 E
No name – to north of Isandara Hill	00°37.811 N
21 July 2007	1359m

Medium-density scatter of slag and tuyére, situated in cultivated land on ridge-top.

KYS18	030°36.814 E
Nyanmongo	00°36.477 N
18 July 2007	1372m

Low-density slag scatter on open northwest-facing hillside and neighbouring compound.

KYS19	030°36.115 E
Buhisi	00°36.573 N
18 July 2007	1386m

Medium-density scatter of slag, pottery (incised lines) and tuyére, on northwest-facing slope.

KYS20	030°35.722 E
Buhisi	00°36.625 N
18 July 2007	1378m

Smelting site, indicated by presence of half-sectioned furnace in road-cut, and accompanying scatter of slag and tuyére. Site is situated on a gentle north-facing slope.

KYS21	030°35.552 E
Buhisi	00°36.652 N
19 July 2007	1412m

Small, low-density scatter of slag and tuyére, and possible furnace base near church on a slight northwest-facing slope and dark brown soils.

KYS22 No GPS reading
Isandara
19 July 2007

High-density slag scatter covering approximately 10m^2, on east-facing slope and dark brown, gravely soils. Surrounding land is very overgrown, only slag visible is on the pathway.

KYS23 No GPS reading
Isandara
19 July 2007

Mining site, on southern slope of Isandara Hill. Most pits have since been filled in.

KYS24 No GPS reading
Isandara
19 July 2007

Low-density slag scatter in banana plantation; probably disturbed by cultivation; dark brown soils; southwest-facing slope.

KYS25 030°34.931 E
Isandara 00°36.870 N
20 July 2007 1384m

Medium-density scatter of slag blocks in slag plantation, which have been disturbed by cultivation. The site is situated on a southwest facing slope, and on dark brown humic soil.

KYS26 030°34.774 E
Isandara B 00°36.843 N
20 July 2007 1386m

Smelting site defined by three small furnaces on a small path in an area of less than 10m^2. Surrounding vegetation makes it difficult to see what else may be around. Site is situated on a southeast-facing slope, on light brown clays.

KYS27 No GPS reading
Rwekunga
20 July 2007

Medium-density scatter of slag blocks, collected from field clearance. Site is situated on a southeast-facing slope on light-brown soils. Highly disturbed by cultivation.

KYS28	030°44.309 E
Kampadwe (nr. Kihura)	00°35.090 N
23 July 2007	1321m

Mining (and possible smelting) site. One mining pit visible, about 1m wide and approximately 3m deep with vertical sides, but travelling horizontally at bottom. A local informant in his 80s (Kamulindwa Johanna) said that smelting was carried out here when he was very young. No evidence of the smelting activity was apparent, i.e. no slag or tuyére, but the area was very overgrown.

KYS29	030°44.559 E
Kyarusura (past Kihora)	00°33.872 N
23 July 2007	1309m

Smithing and smelting site, with medium-density scatter of slag, tuyére and pottery (KPR and TGR). The family who live in this compound are of the Bangeri clan and have always practiced metallurgy. The site is situated within their ridge-top compound, which is relatively undisturbed, and extends for approximately 30m^2.

KYS30	030°44.315 E
Kampadwe Hill	00°34.948 N
23 July 2007	1373m

Five mining pits over an area of approximately 100m^2. Very bushy, southeast-facing hillside. All the pits have now been filled in.

KYS31	030°39.952 E
Ndama	00°31.567 N
24 July 2007	1397m

Medium-density slag and pottery (KPR) scatter in a compound and surrounding agricultural land on a southeast-facing slope. The site is very disturbed due to cultivation.

KYS32	030°38.035 E
Mukeye	00°35.105 N
24 July 2007	1399m

Low-density slag scatter over and area of 35m^2. High potential for disturbance as on agricultural land with surrounding bushland.

KYS33	030°38.599 E
Nyarukoma	00°33.779 N
24 July 2007	1399m

Low-density slag and tuyére scatter over an area of approximately 35m^2. Also, a possible furnace base on the road, but possibility of excavation is unlikely as it's a very fast road.

KYS34	030°39.120 E
Nyarukoma	00°32.880 N
24 July 2007	1397m

Possible piece of smithing slag – isolated find spot.

KYS35	030°39.562 E
Kipeepa	00°34.216 N
24 July 2007	1390m

Past smelting site until the 1920s/1930s, but very little evidence on the surface to suggest this now except for a single large slag block. The local LC2 showed us a place under a tree where his father and grandfather used to smith and smelt. Reddish-brown soils and situated on ridge-top.

KYS36	030°35.223 E
Rwabakaikuru	00°49.484 N
25 July 2007	1449m

Medium-density slag and pottery scatter, with lots of different pottery types, including some possible Urewe. Site is situated on way to Mparo, in a compound on the ridge top. It's likely that there is a fair amount of disturbance due to agriculture.

KYS37	030°35.266 E
Rwabakaikuru	00°49.368 N
25 July 2007	1445m

High-density scatter of large slag blocks and pottery (TGR, KPR) over an area of approximately 50m^2. Site is situated close to KYS36, in a banana plantation down-slope from the ridge top. It is southeast-facing on reddish-brown soils, and it is likely to be highly disturbed due to the banana cultivation. One large slag block showed external morphology suggestive of slag tapping.

KYS38	030°37.255 E
Mparo	00°50.611 N
25 July 2007	1445m

Medium-density slag scatter over an area of approximately 10m^2. The concentrated nature of the slag suggests a possible slag dump, or past (highly efficient) field clearance. The site is situated in agricultural land adjacent to a compound, on reddish-brown soils, facing northeast. Very difficult to get to with a vehicle.

KYS39	030°37.125 E
Mparo	00°50.389 N
25 July 2005	1368m

Smelting site, indicated by the presence of a disturbed furnace base, slag and tuyéres in the road to the primary school at Mparo. Low-density of finds, and highly disturbed, as situated directly on road.

KYS40	030°36.268 E
Kasaba Rwabasigazi	00°50.002 N
26 July 2007	1376m

Medium-density scatter of slag, tuyére and pottery (KPR, TGR) over an area of approximately 20m^2, about 2km from Kasaba trading centre. Scatter consists mainly of small slag fragments, but there are also some larger pieces. Site is situated on a gentle southeast-facing slope, on dark brown soil, in cultivated garden of a compound.

KYS41	030°36.292 E
Muhabura	00°50.680 N
26 July 2007	1358m

Medium-density slag scatter of slag and pottery (KPR, TGR), over an area of approximately 1000m^2, with the disturbed remains of a furnace base. The site is situated on an open road surrounded by cultivated land, on compacted reddish-brown soils, on a west-facing slope.

KYS42	030°36.234 E
Muhabura	00°50.842 N
26 July 2007	1319m

Low-density slag scatter on disturbed, agricultural land. Very difficult to access.

KYS43	030°36.608 E
Kasaba B	00°49.164 N
26 July 2007	1379m

Possible smelting site on agricultural land, with a medium-density scatter of furnace bottom slags and tuyére. The site is situated on a north-northeast-facing slope with dark soils, and is highly disturbed.

KYS44	030°30.433 E
Rugombe Kasozi	00°39.729 N
27 July 2007	1599m

Mining site within Ruha forest, on west-facing slope of commercially forested hillside. Mining pits are said to have completely covered the hillside, but most have since been filled in to facilitate the planting of fir trees. Small shallow holes mark where each pit was. Some pits on top of the hill, however, have been left unfilled.

KYS45	030°29.925 E
Rubona Kakingo	00°38.546 N
27 July 2007	1591m

Low to medium-density scatter of slag blocks in area of what is traditionally thought to be an area for smelting, covering an area of approximately 2500m^2. Surprisingly, no tuyéres found. The site covers agricultural land on the southeast-facing slope of Rubona, on loose, dark soils, and is quite disturbed. Access is from the main Kyenjojo-Fort Portal road, taking a left-hand turn just before Rugombe.

KYS46	030°45.325 E
Kijumba	00°32.298 N
23 July 2007	1335m

Low-density scatter of slag and pottery (undecorated), over an area of approximately 80m^2. The site is situated near Kijumba Gospel of the Holy Seed Church, in bushy land on a northeast-facing slope. There is little potential for excavation as it is highly disturbed by road construction.

KYS47	030°37.127 E
Makarra ("charcoal")	00°44.228 N
25 July 2007	1479m

Probably smelting site, indicted by very high-density scatter of slag blocks and pottery in a grass-covered pile over an area of about 50m^2. Site is situated in a compound near the road, on a gentle southwest-facing slope, on dark brown soils. Further investigations would be interesting here, and there is potential for further archaeological remains to be exposed from under the current thick vegetation.

KYS48	030°34.964 E
Makarra (“charcoal”)	00°44.169 N
25 July 2007	1488m

High-density scatter of slag, tuyére and pottery (KPR), suggesting a possible smelting site. Has good potential for further excavation. Site is situated near the forest of Makarra Hill, on a northwest-facing slope and dark brown soils. Easy access to the site, as compound with remains is just off the road.

KYS49	No GPS reading
Rebuni/Bihanga	
25 July 2007	

Low-density scatter of slag and pottery (KPR, Urewe) over an area of 15m^2, on the southeast-facing slopes of a rocky hillside. Potential for disturbance is high and the site is not recommended for excavation.

KYS50	030°32.499 E
Kyanjubu	00°45.143 N
26 July 2007	1469m

Low-density slag and pottery scatter, over an area of about 20m^2 on the northeast-facing slopes of a tea plantation.

KYS51	030°30.878 E
Nyamabuga	00°42.522 N
26 July 2007	1506m

Low-density slag, bone and pottery (TGR, KPR) scatter on road towards Nyamabuga Health Centre. The high vegetation cover on either side of the road means that little could be understood about the true nature of the remains, but the finds extend for a minimum of 15m along the road. The site is situated on a south-facing slope, on light brown soils, and the potential for disturbance is high.

KYS52	030°31.180 E
Butara	00°40.567 N
27 July 2007	1516m

Low-density scatter of slag on roadside, extending for approximately 10m. The road cut has exposed a layer of slag in the bottom parts. The site is situated on a south-facing slope and dark brown soils.

KYS53	030°30.607 E
Rugombe II	00°40.021 N
27 July 2007	1548m

Low-density scatter of slag and pottery, and the remains of a small furnace base in the road section, suggestive of a smelting site. The site is situated very close to Rugombe trading centre, on the road heading north from there. It is on a moderate, south-facing slope and light brown soils, and the site extends over approximately 100m^2. According to the road cut, the layer of slag and furnace lies approximately 1.5m below the surface.

KYS54	030°30.222 E
Rugombe I	00°39.935 N
27 July 2007	1528m

Medium to high-density scatter of slag blocks, tuyére and pottery in Rugombe trading centre, with the well-preserved remains of a furnace base.

KYS55	030°35.102 E
Binunda	00°45.656 N
30 July 2007	1529m

High-density scatter of slag, tuyére and KPR pottery over an area of 15m^2. The layer of deposits appear to extend 1m deep. The site is situated in agricultural land, on a gentle south-southeast-facing slope on loose dark soils. The site is likely to be highly disturbed due to agricultural activity.

KYS56	030°37.492 E
Nyabyenga ("place of slag")	00°47.009 N
30 July 2007	1379m

Medium-density scatter of medium-sized slag blocks and tuyére over an area of approximately 300m^2. A layer of about 20cm of medium-brown soils is visible in the road cut, and the site seems to relatively undisturbed – the slag blocks seem semi-buried and covered in bush and grass. The site is situated on the edge of a forest, about 500m before the town itself, on the edge of the football pitch, and on a gentle northeast-facing slope. Some pottery (KPR).

KYS57	030°37.766 E
Nyabyenga ("place of slag")	00°47.363 N
30 July 2007	1319m

High-density scatter of slag and tuyére on agricultural land over an area of about 750m^2. The site is situated on a west-facing slope on dark, loose soils, and the site is likely to be highly disturbed. Some pottery (KPR).

KYS58	030°39.130 E
Kyakaturi	00°45.930 N
30 July 2007	1329m

Furnace base visible in path on moderate south-facing slope.

KYS59	030°39.116 E
Kyakaturi	00°45.964 N
30 July 2007	1332m

Very high-density scatter of slag and tuyére in compound, on southeast-facing slope, over an area of approximately 15m^2. Some pottery (TGR).

KYS60	030°39.950 E
Buhuro	00°45.683 N
31 July 2007	1376m

High-density scatter of slag and tuyére in church and private compounds over an area of about 100m^2. Some pottery (KPR, Urewe). Shallow deposits, but very dense. Could be interesting to excavate. Considered to be a major smelting place for the surrounding areas; a key place for smelting.

KYS61 ≈ KYS62	030°41.378 E
Kakoni	00°46.926 N
31 July 2007	1357m

Low-density pottery scatter (incised lines) in path, very close to KYS62, interesting decoration. Path passes through agricultural land on a north-facing slope, high levels of water erosion, red, compacted soils.

KYS62 ≈ KYS61	030°41.373 E
Kakoni	00°46.948 N
31 July 2007	1362m

Heavily eroded remains of two furnace bases, with some tuyére and slag. Site is on pathway, sloping north-northeast, on red, compacted soils and surrounded by agricultural land.

KYS63	030°41.893 E
Karuruga	00°46.935 N
31 July 2007	1396m

High-density scatter of slag and tuyére over an area of approximately 15m^2. The site is situated on an open road, and within farmland, on a south-southwest-facing slope and reddish brown soils. There is a reasonable level of disturbance. Some pottery (KPR, TGR).

KYS64	030°41.329 E
Kikoni	00°46.105 N
31 July 2007	1397m

Medium-density scatter of slag blocks, approximately 30 blocks, but likely to have been collected from nearby fields.

KYS65	030°40.226 E
Nyamwandara ("place of flat rock")	00°41.822 N
1 August 2007	1364m

Low-density slag and pottery scatter (KPR) over an area of 400m^2, on disturbed, agricultural land, on a west-northwest-facing slope and dark red soils. This is also a place where Kabayo, the first king of Toro, who broke away from Bunyoro, is said to have rested under a tree.

KYS66	030°38.241 E
Kigumba	00°41.160 N
1 August 2007	1351m

Low-density slag, pottery and tuyére scatter of approximately 35m^2, in the middle of a tea plantation on a northwest-facing slope, on the road between Kigumba and Rwamukora. Difficult to see ground amongst the tea, and not recommended for excavation – highly disturbed.

KYS67	030°37.843 E
Katebe (Mubyenga, "of slag")	00°42.943 N
1 August 2007	1338m

Smelting site, situated towards top of hill on gentle east-facing slope. A very high-density of smelting remains, such as large slag blocks and tuyére fragments, has recently been cut through by road construction. The site is clearly defined in the road cut, by a thick lens of very dark brown, ashy soils. Some pottery (incised lines). There's scrubland on one side of the site, farmland on the other, divided by the road. Nearby mining site at Kalebaleba (recorded separately).

KYS68	030°41.157 E
Mubibale Kabatolo	00°44.800 N
2 August 2007	1377m

High-density scatter of large slag blocks over an area of about 100m^2. Slag exposed on the road surface by erosion, and there are further isolated slag blocks in surrounding fields. The site is situated on a southwest-facing slope near Nyankisi trading centre.

KYS69 030°43.181 E
Kamayoso 00°44.244 N
1 August 2007 1357m

Low-density slag and pottery (KPR, TGR, incised lines) scatter over an area of about 400m^2. Slag pile mainly consisting of slag fragments rather than blocks, as a result of field clearance. The site is situated in agricultural land on a northeast-facing slope, but the land is likely to be highly disturbed.

KYS70 030°44.918 E
Kakuba ("a red bead") 00°43.618 N
2 August 2007 1357m

Low-density slag scatter, consisting of unusually small complete slag blocks, retrieved from about 1 foot underground whilst digging gardens. The site is situated on hilly agricultural land, on a west-facing slope, on the road to Kahanda.

KYS71 030°41.545 E
Munjeru 00°42.897 N
2 August 2007 1368m

Low-density slag scatter close to the main road running north from Kyenjojo towards Hoima, in a place used now for making bricks. The site is on a northwest-facing slope and is quite heavily disturbed by a local brick-making industry.

KYS72 030°37.288 E
Rwengibe 00°40.006 N
2 August 2007 1354m

Low-density slag and pottery (KPR) scatter with a possible furnace base. The possible furnace seems to contain the remains of a small pot, and may be interesting to investigate further. The site is on open land within a compound, on a gentle southeast-facing slope, and possible disturbance maybe relatively minimal.

KYS73 030°28.108 E
Kyansagi 00°41.196 N
3 August 2007 1507m

Low-density slag and pottery scatter, covering an area of approximately 30m^2. The slag is in the form of medium-sized slag blocks, and the site is situated on agricultural land, on a southeast-facing slope.

KYS74 030°28.033 E
Mabale ("stones") 00°42.317 N
3 August 2007 1515m

Medium-density scatter of slag blocks, that has prevented the land from being cultivated. The area covers about 400m^2. The site is situated within bushy, overgrown land on a north-northwest-facing slope. Surface conditions mean that the site may remain relatively undisturbed.

KYS75 030°28.192 E
Mabale – Kyawako 00°42.195 N
3 August 2007 1520m

Low-density slag and pottery (TGR, KPR) scatter over an area of approximately 600m2. There are high levels of erosion in the area due to steep slopes, and no features visible, so excavation is not recommended. The site is situated in agricultural land, and on dark brown soils, concentrated mainly in the compound of a man named Agab.

KYS76 030°28.171 E
Mabale Kyawako 00°42.246 N
3 August 2007 1542m

Burnt area in road, roughly circular, with high concentration of slag and a lot of charcoal – possible furnace? The road surface lies about 3m below the level of the surrounding agricultural land. Close to KYS75.

KYS77 030°28.982 E
Kahungera 00°40.805 N
3 August 2007 1512m

Smelting site on a path near a banana plantation, indicated by the remains of a furnace base and tuyére, slag and pottery (KPR) over an area of 25m^2. Has good potential for excavation, and is not particularly disturbed.

KYS78 No GPS reading
Mitooma
3 August 2007

Low-density scatter of slag and pottery over an area of 20m^2, with the remains of a furnace exposed in the road section. Highly disturbed by the road construction.

KYS79 No GPS reading
Mitooma
3 August 2007

Low-density scatter of slag, tuyére and pottery over an area of 10m^2 within the church compound. Low potential for excavation and highly disturbed.

KYS80 No GPS reading
Mitooma
3 August 2007

Low-density scatter of slag, tuyére and pottery over an area of 20m^2 in road. Low potential for excavation.

KYS81 No GPS reading
Kyairumba
3 August 2007

High-density scatter of large slag blocks over an area of about 10m^2 within a banana plantation on dark brown, humic soils. Thick banana plantation means that ground visibility was very limited.

KYS82 030°34.826 E
Kanshamba ("dry place") 00°41.122 N
6 August 2007 1542m

Medium-density scatter of slag and tuyére in the road over an area of about 20m^2. The site has been disturbed by the road construction, and is situated on a southeast-facing slope and dark brown soils. Has low potential for archaeological investigation.

KYS83 030°34.836 E
Kyakatumba 00°41.841 N
6 August 2007 1384m

Low-density scatter of small slag fragments, pottery (KPR) and tuyére over an area of 10m^2 on a road surface. The site is situated on a north-northeast-facing slope with mid-brown soils, and is quite disturbed. Low potential for excavation.

KYS84 030°35.700 E
Nyansokya 00°41.273 N
6 August 2007 1358m

High-density scatter of slag and tuyére, with good preservation of materials. Site is situated on agricultural land on a southeast-facing slope.

KYS85 030°28.813 E
- 00°39.663 N
7 August 2007 1551m

Low-density scatter of slag and pottery (TGR) along a small path, on a north-facing slope and mid-brown soils. Site extends over about 40m^2, and the archaeological remains are coming from a layer about 30cm beneath the surface.

KYS86 030°27.857 E
Kasamba 00°38.527 N
7 August 2007 1498m

Medium-density scatter of slag and charcoal disturbed during road construction, about 40cm below the ground surface. Site is southwest-facing and on dark brown soils.

KYS87 030°28.755 E
Kisamulongole 00°39.372 N
7 August 2007 1508m

Medium-density scatter of pottery (KPR) and slag blocks, over an area of about 20m^2. Site is situated on agricultural land, on a southwest-facing slope and dark humic soils. Area has been over-cultivated though, so the site is very disturbed.

KYS88 030°25.765 E
Nyalubira 00°38.053 N
7 August 2007 1360m

Low-density slag, pottery (TGR, KPR) and tuyére scatter over an area of 600m^2 in a tea plantation bordering Kibale Forest Reserve. The site is situated close to the top of a northeast-facing slope on mid-brown soils, and is highly disturbed due to being within a tea plantation. Occasional slag blocks; frequent small-medium slag fragments.

KYS89 030°27.552 E
Biara ("to plant") 00°38.118 N
7 August 2007 1510m

Moderate-density scatter of pottery (TGR) and slag over an area of approximately 600m^2. Thin layer of small slag fragments and pottery at about 25-30cm beneath the surface (section exposed behind house). This rich, black/brown layer extends to about 35cm deep, sitting on top of orange/red soils. Small slag fragments are also visible in the road. The site is situated in agricultural land on a north-facing slope, and has been disturbed by digging gardens.

KYS90	030°27.580 E
Biara ("to plant")	00°37.349 N
7 August 2007	1478m

High-density scatter of tuyére, slag and pottery (KPR, incised lines) over an area of about 1200m^2, including a large number of slag blocks. Mining pits nearby (KYS91). The site is situated in a compound surrounded by agricultural land, towards the bottom of a southwest-facing slope, on dark brown soils, and has been heavily disturbed by banana plantation.

KYS91	030°27.557 E
Biara ("to plant")	00°37.277 N
7 August 2007	1482m

Mining site, comprising around 50 pits on a forested and bushy hillside, on a south-facing slope.

KYS92	030°27.646 E
Biara ("to plant")	00°37.499 N
7 August 2007	1479m

Low-density slag and pottery (KPR, incised lines) scatter on an open road surrounded by agricultural land. The site extends over an area of about 15m^2, and is on dark black-brown soils. There is a quite high level of disturbance because of digging.

KYS93	030°27.777 E
Biara ("to plant")	00°37.848 N
7 August 2007	1534m

Low-density slag scatter on road surrounded by agricultural land. Highly disturbed.

- There is no KYS94 (KYS95 incorrectly labelled) -

KYS95	030°29.748 E
Rubona Kakingo	00°38.523 N
8 August 2007	1576m

Low-density slag and pottery scatter over an area of about 10m^2. Possible Urewe pottery. The site is situated on open and agricultural land, on a northwest-facing slope, and is on mid-brown soils. It is likely that it is disturbed.

KYS96	030°30.023 E
Rubona Kabingo	00°37.841 N
8 August 2007	1483m

Low-density scatter of slag, pottery and tuyére over an area of about 15m^2. Heavily disturbed by cultivation. Site is situated within a banana plantation, on mid-brown soils.

KYS97 & KYS98	030°30.110 E
Mirongo	00°37.023 N
8 August 2007	1523m

Low-density slag and pottery (TGR, KPR) scatter, found by both survey teams independently. Slag is in form of medium slag blocks, and has been collected from surrounding gardens. The site is situated in a compound surrounded by agricultural fields, midway on an east-northeast-facing steep slope and reddish soils.

KYS99	030°29.102 E
Lwensenene	00°36.357 N
8 August 2007	1466m

High-density scatter of slag, tuyére and pottery (TGR, KPR) over an area of approximately 400m^2. Lots of small slag fragments cleared from a field and a medium slag block, although more are said to remain underground. The site is situated on a north-northwest-facing slope on dark brown soils.

KYS100	030°29.021 E
Lwensenene	00°36.256 N
8 August 2007	1476m

Mining site. Large number of 'enambo' covering scrub-covered, south-southwest-facing hillside, over an area of about 1200m^2. Most filled in order to prevent cattle falling in them, but some are still open and are very deep.

KYS101	030°29.626 E
Cikandwa	00°35.241 N
8 August 2007	1409m

High-density slag, pottery and tuyére scatter in compound pathways and surrounding agricultural fields. Some possible Urewe pottery and slag blocks. The site is situated over an area of approximately 7500m^2, and there is a tradition in the area of smelting. It is on a northeast-facing slope, on light brown soils, but the area has been highly disturbed by cultivation.

KYS102	030°28.956 E
Rukomero I (“fence, barricade”)	00°35.726 N
8 August 2007	1449m

Very high-density pottery scatter (KPR, TGR, Urewe) with some small pieces of slag, over an area of about $35m^2$. Very many pottery types represented on bare, swept ground, on a northeast-facing slope on reddish brown soils.

KYS103	030°28.986 E
Rukomero II (“fence, barricade”)	00°36.095 N
8 August 2007	1444m

Smelting site indicated by the presence of two furnace bases eroding out of pathway leading down to an open area of a compound, damaged on the surface by cattle movements and water. Site is situated on a steep, southwest-facing slope on reddish brown soils. Very little pottery and no slag in immediate area of furnace, but lots of pottery (TGR) in road above compound.

KYS104	030°28.938 E
Rukomero III (“fence, barricade”)	00°35.885 N
9 August 2007	1447m

High-density slag and pottery scatter (KPR, TGR) in road cut for about 30m – area being dug by hoe. Rich, ashy deposits visible in road cut – possibly high potential for pottery sequence? The site is situated on a south-southwest-facing slope, on dark brown/reddish soils in a heavily cultivated area.

KYS105	030°28.318 E
Rwabaganda	00°35.656 N
9 August 2007	1420m

Medium-density slag and pottery scatter (KPR, TGR) in agricultural fields – slag is being dug from about 1 foot down in a banana plantation. There are six main piles of slag collected from field clearance. The site is situated on a northeast-facing slope on reddish brown soils.

KYS106	030°30.036 E
Kyabikanga	00°36.709 N
9 August 2007	1457m

Mining site, consisting of approximately 50, vertical-sided mining pits, about 20-25m in depth. Site is situated on a steep hillside with some cultivation and some eucalyptus trees. The soils are very thin, and grey-orange.

KYS107 030°36.705 E
Rwenkuba 00°39.091 N
10 August 2007 1354m

Mining site, consisting of two large 'enambo' about 2m in diameter and approximately 50 feet deep. Filled in about 30 years ago and very heavily overgrown. The pits are situated on a very steep west-facing hillside, which is very bushy.

KYS108 030°37.425 E
Kigando 00°38.814 N
10 August 2007 1352m

Very low-density slag scatter over an area of about 25m^2. Some slag bocks, which were discovered when digging pits to plant bananas. Very little visible on surface. The site is situated on agricultural land, on a gentle southeast-facing slope, on rich dark reddish brown soils.

KYS109 030°37.234 E
Rwenkuba 00°39.061 N
10 August 2007 1360m

Medium-density slag scatter over an area of about 50m^2. Occasional pottery pieces KPR). Large slag blocks have also been revealed whilst digging for sweet-peas, not buried that far underground. The site is situated on a very gentle east-northeast-facing slope, near the hilltop. The soils are dark red.

KYS110 030°36.067 E
Ihamba ("wilderness, solitude") 00°33.747 N
10 August 2007 1368m

Mining site consisting of approximately 50 pits on a small, flat hilltop. Pits are about 2m in diameter with vertical sides. Most pits have now been filled in.

KYS111 030°31.178 E
Kisamura 00°39.486 N
9 August 2007 1490m

Smelting site indicated by a heavily-eroded furnace base, and accompanying slag and pottery (KPR) scatter over an area of about 200m^2. A few scatters of slag blocks are also in evidence. The site is situated in agricultural land (banana plantation) on a south-facing slope, on mid-brown soils. Local people mentioned mining on Mukunyu Hill.

KYS112 No GPS reading
Kisamura
9 August 2007

Low-density scatter of slag and pottery (KPR), with several piles of slag collected from field clearance. Site is situated on agricultural land on a northwest- facing slope, on mid-brown soils over an area of about 100m^2. The site is highly disturbed by cultivation and has low potential for excavation.

KYS113 No GPS reading
Kisamura
9 August 2007

Low-density scatter of slag and pottery (KPR) in south-facing banana plantation on mid-brown soils. Probably highly disturbed by agriculture.

KYS114 030°41.655 E
Kyakaturi 00°36.881 N
10 August 2007 1342m

Low-density scatter of pottery, slag and tuyére over an area of about 5m^2, plus the remains of a small furnace wall in the road section, at a depth of about 80cm-1m. Site is situated on a southeast-facing hillside in a bushy area, on mid-brown soils.

KYS115 030°31.384 E
Kasoga ("a dark salt") 00°37.170 N
30 August 2007 1454m

Medium-density slag and pottery scatter (TGR) over an area of about 20m^2. Site is situated on a northwest-facing slope, on dark brown humic soils of a banana plantation. Heavily disturbed by cultivation. Some large blocks of slag collected from field clearance.

KYS116 030°38.968 E
Kyakaturi 00°45.841 N
13 September 2007 1331m

High-density scatter of slag blocks over an area of about 70m^2 on land that isn't farmed due to the high concentration of slag in the ground. Soils are rich brown.

KYS117 030°38.852 E
Kyakaturi 00°45.885 N
13 September 2007 1326m

Low-density scatter of slag blocks and fragments over an area of 25m^2. Site is situated on a northwest-facing slope leading down to a steep valley, in compounds and surrounding bush land, on rich brown soils. High levels of vegetation, difficult to see slag blocks.

KYS118	030°38.344 E
Kagorra ("a kind of millet")	00°46.521 N
13 September 2007	1326m

Mining site on steep, wooded hillside on the west-facing side. Very difficult to find pits as the undergrowth is very thick, and all pits that were located had been filled in. Also said to be three other areas of 'enambo' on Kagorra Hill, but they have now all been filled in by the Forestry Commission.

KYS119	030°37.603 E
Katebe	00°43.326 N
14 September 2007	1331m

Mining site on open grazing land on gentle, north-facing slope with reddish-brown, silty soils. The pits are of various sizes, mostly 2m in diameter, but one especially large one was 5-6m in diameter. All have been filled in. About 15 to 20 pits over about 100m^2.

KYS120	030°33.779 E
Kirongo	00°35.919 N
19 September 2007	1441m

High-density scatter of slag and pottery, consisting mainly of two large piles of slag in an area of about 200m^2. There are probably about 50-100 slag blocks, mostly buried in these two large piles. Site is situated on a shallow gradient south-facing slope, on grazing land with dark-brown clayey-silts. Close to 'enambo' (KYS16) and excavation site (KYS15). High potential for excavation, but we had problems obtaining permission from the landowner.

Kooki Survey

KOKS1	031°28.693 E
Kanoni	00°39.635 S
3 October 2007	1215m

High-density slag and pottery scatter (painted KPR, possible TGR) over an area of about 5000m^2 (100m x 50m). Slag is in form of both furnace slag blocks, with a peculiar v-shape in profile and slag fragments. Site is situated on agricultural land on a south-southeast-facing slope, on very thin, light grey soils. We were told that a traditional tree used for smelting was *munaza* (i.e. date palm).

KOKS2	031°28.961 E
Kayunga	00°38.928 S
3 October 2007	1217m

Very low-density scatter of slag and undecorated pottery over an area of about 150m². Apparently, most of the slag has been taken away for building, and there is low potential for excavation as the area is highly cultivated. The site is situated in banana fields on a north-facing slope, on brownish-grey soils.

KOKS3	031°28.293 E
Kanoni	00°39.389 S
3 October 2007	1217m

High-density scatter of slag and tuyére over area of about 225m², suggestive of a smelting site. Smelting was supposed to have occurred here until 1953. The site is situated in a large depression in agricultural land, on a gentle west-facing slope, on brownish-grey soils.

KOKS4	031°27.737 E
Mpaama ("poor soil, hard earth")	00°38.669 S
3 October 2007	1239m

Medium-density scatter of slag and tuyére over an area of about 150m². Probably over 100 large slag blocks, comprising three slag piles, some slag blocks reaching about 1m in diameter. The site is situated on agricultural land on a south-facing slope, on dark greyish-brown soils.

KOKS5	031°27.946 E
Luteebe	00°38.306 S
3 October 2007	1231m

High-density slag and pottery scatter (TGR) over an area of about 625m², with a large pile of large slag blocks (approx. 60-80cm in diameter), which measures about 15m long by 5m wide and 2m deep. Many slags have apparently been taken away for building or for wells, but a lot are said to remain buried at this site. The site is situated in bush-land behind a banana plantation, on a gentle, east-facing slope, on greyish-brown soils.

KOKS6	031°27.666 E
Luteebe	00°37.808 S
3 October 2007	1234m

Low-density slag and pottery scatter over an area of about 24m². Several complete furnace slags, but again, many have been removed for building. Site is situated on disturbed agricultural land on an east-facing slope, on dark brown soils.

KOKS7	031°27.651 E
Kijumba	00°37.227 S
3 October 2007	1224m

Dense slag scatter and deep pile of large slag over an area of about 50m². Site is situated in agricultural land, although the direct area of the slag pile is covered in scrub. The site is on a steep northeast-facing slope, on thin and sandy brown soils. Due to the density of the remains, they have been mainly left alone, although some slag blocks have apparently been taken away for building.

KOKS8	031°27.697 E
Kijumba	00°37.133 S
3 October 2007	1208m

High-density scatter of slag and tuyére over an area of about 80m², but hidden under tall grasses. Site is situated on agricultural land on an east-facing slope, on dark brown soils. Quite disturbed by cultivation.

KOKS9	031°27.455 E
Kijumba	00°37.183 S
3 October 2007	1249m

High-density scatter of slag, pottery and tuyére over an area of about 20m², consisting mainly of a very large pile of slag, about 10m long and 2m high. The site is situated in a field of peas, on a gentle northeast-facing slope just underneath a rocky outcrop.

KOKS10	031°29.005 E
Kituntu ("high ground")	00°40.997 S
4 October 2007	1238m

Low-density scatter of slag and pottery (KPR and TGR) over an area of about 50m². Mainly consists of small piles of slag blocks moved during field clearance, with very little pottery. The site is situated in scrubland, which is lying fallow of coffee and cassava, on a very gentle northwest-facing slope coming down from Mbuye Hill, on brownish-grey sandy-silt. The area is highly disturbed by cultivation, and some slag blocks have also been moved during field clearance.

KOKS11	031°29.551 E
Selinya A	00°41.304 S
4 October 2007	1233m

Low to medium-density scatter of slag and pottery (KPR, red painted) over an area of 25m². Small pile of small slag fragments in the corner of a banana plantation – localised pile, not much slag elsewhere. The site is situated on agricultural land, on a gentle, northwest-facing slope, facing the southeast slope of Mbuye Hill, on dark greyish-brown silty sand.

KOKS12 031°29.641 E
Selinya 00°41.206 S
4 October 2007 1225m

Medium-density scatter of slag and pottery in banana plantation, on a very slight north-northeast-facing slope on greyish-brown, sandy silt.

KOKS13 031°29.954 E
Kiyovu 00°40.652 S
4 October 2007 1224m

Medium-density scatter of slag blocks and fragments over $40m^2$, many being used to mark tombs. May have been moved from nearby fields. Site is situated on agricultural land on dark brown soils.

KOKS14 031°30.048 E
Sirinya 00°41.415 S
4 October 2007 1197m

Low-density scatter of slag, tuyére and pottery (TGR) over $100m^2$. Site is situated on an open, gentle east-facing slope with thin soils covering an iron and quartz-rich bedrock. A much higher concentration of slag blocks was found slightly uphill, in a very overgrown patch [031°29.980 E, 00°41.458 S, 1206m].

KOKS15 031°29.249 E
Lusolo ("termite" or *bao* board) 00°42.074 S
4 October 2007 1200m

Medium-density scatter of slag and tuyére over an area of about $50m^2$, with several slag fragments and lots of tuyére. The site is situated on agricultural land, on a southeast-facing slope, on dark brown soils.

KOKS16 031°28.883 E
Lwanda sub-county HQ 00°40.422 S
4 October 2007 1214m

Low-density scatter of slag within the sub-county compound. Occasional blocks of slag in paths and grass over an area of about $700m^2$. Site is situated on a slight northwest-facing slope on mid-brown sand-clay-loam, with possible heavy disturbance from construction of buildings and drainage ditches.

KOKS17 031°21.832 E
Kiwesi ("place of the smiths") 00°37.421 S
5 October 2007 1216m

Smelting site indicated by high-density scatter of slag, tuyére and pottery (TGR, KPR) over an area of $700m^2$, with the additional presence of a furnace base. Site is situated on agricultural land and compounds, on a moderate southeast-facing slope, on medium brown sandy silt.

KOKS18	031°23.210 E
Lutete	00°36.181 S
5 October 2007	1341m

Medium-density scatter of slag and tuyére over an area of about 50m^2. Some pottery (TGR). Approximately 50 furnace base slags. Site is situated on agricultural land, on the upper part of a steep hill, on a west-northwest-facing slope on dark brown soils.

KOKS19	031°23.425 E
Kitezi	00°35.305 S
5 October 2007	1333m

Medium-density scatter of slag, comprising three piles of slag blocks and slag fragments from field clearance over an area of about 150m^2. The site is situated on an east-northeast-facing, moderate slope in a very overgrown patch of scrub next to agricultural fields on light-orangey-brown, sandy soils. Complete slag blocks are smaller than typical slag in this region (c. 30cm in diameter rather than c. 80cm).

KOKS20	031°22.258 E
Katera	00°33.867 S
5 October 2007	1343m

High-density scatter of slag and tuyére over an area of about 150m^2. Approximately 300 medium-sized slag blocks in a pile of about 10m long by 3m deep and 1.5m high. Site is situated on agricultural land, on a west-facing slope on dark brown soils.

KOKS21	031°21.897 E
Lwandaula A	00°33.340 S
5 October 2007	1275m

Low-density scatter of slag moved during field clearance. Apparently much of the slag had been taken away for use as temper in making pottery. Site is situated in an area of banana cultivation on a southeast-facing slope, on light brownish-grey, sandy silt. There is also said to be the remains of iron ore mining on the nearby hill of Kabugara.

KOKS22	031°27.074 E
Kabale ("pebble")	00°36.417 S
3 October 2007	1297m

High-density scatter of slag blocks and tuyére, over an area of 150m^2, which seems likely to be a smelting site due to the large number of remains. Some pottery (KPR). There is also a shallow depression of about 2-3m in diameter, which may also be related to iron production. The site is situated in a banana plantation area of a compound on a northwest-facing slope on sandy silt.

KOKS23 031°24.806 E
Nsozibiri 00°38.446 S
3 October 2007 1315m

Very high-density scatter of slag, tuyére and pottery with large blocks of slag and a potential furnace base. However, the slags are said to have been brought from Nakitokolo. The site is situated on a small road surrounded by banana plantations, on a north-facing slope, on silt with gravels.

KOKS24 031°24.960 E
Kinundamaliga 00°40.097 S
3 October 2007 1251m

High-density scatter of large slag blocks over an area of about 300m^2 – the slag blocks have been collected from field clearance. The site is situated in a banana plantation, on a west-facing slope on sandy silt.

KOKS25 031°24.961 E
Nsozibiri 00°39.210 S
3 October 2007 1260m

High-density scatter of slag fragments over an area of about 100m^2. Site is situated on agricultural land immediately to the west of the main road heading northwest out of Rakai. Site is on a slight, west-facing slope on sandy silt.

KOKS26 031°24.543 E
Nsozibiri 00°38.798 S
4 October 2007 1282m

High-density scatter of slag and tuyére over an area of 150m^2, possibly suggestive of a smelting site. Some pieces of burnt ceramic may be the broken remains of a furnace wall. Site is situated on the edge of a banana plantation on agricultural land, on a gentle, south-facing slope with clay loam. Highly disturbed.

KOKS27 031°24.689 E
Nsozibiri 00°38.769 S
4 October 2007 1292m

High-density scatter of slag blocks and tuyére over an area of about 400m^2. Site is situated on a narrow road through thick bushes, surrounded by agricultural land. The site is on a southeast-facing slope on clay loams, and has also been subject to some erosion.

KOKS28	031°26.373 E
Syengenja	00°39.063 S
4 October 2007	1260m

High-density scatter of large slag blocks over an area of approximately 400m^2. Slag blocks are dispersed throughout compound, and haven't been piled. Site is situated on a west-facing slope on silty loam, within a banana plantation, meaning there is likely to be some disturbance.

KOKS29	031°28.118 E
Mukunyu ("wild fig tree")	00°39.826 S
4 October 2007	1269m

Medium-density scatter of slag, tuyére and possible furnace wall, including some large slag blocks in road. Site is situated in agricultural land in a banana grove on a north-facing slope, but is likely to be highly disturbed. Site is on very dark greyish brown sand-clay-loam.

KOKS30	031°22.500 E
Kanamuzinzi	00°41.310 S
5 October 2007	1251m

High-density scatter of slag blocks and tuyéres, mostly buried in the ground along the side of the road, over an area of about 200m^2. Site is situated on a south-facing slope on sandy-silt.

KOKS31	031°23.072 E
Mikoni	00°40.828 S
5 October 2007	1260m

Low-density scatter of slag blocks in banana plantation and in road, over an area of about 150m^2. Site is situated on a very gentle, southwest-facing slope, on sandy clays, with some disturbance from cultivation.

KOKS32	031°25.458 E
Nsozibiri	00°38.865 S
4 October 2007	1288m

Isolated find spot: lithic – possible hand axe or stone spear.

KOKS33	031°21.916 E
Kyanyegenyege	00°37.380 S
15 October 2007	1268m

Low-density scatter of slag and tuyére over an area of 75m^2. Site is situated on agricultural land on a southwest-facing slope, on light brown silty soils. Site is highly disturbed and not recommended for excavation.

KOKS34	031°17.357 E
Kirangira	00°35.643 S
16 October 2007	1250m

High-density scatter of slag and tuyére over an area of about 1600m^2. There is also a large circular depression which may be linked to smelting, and the site itself is attributed to smelting by the grandparents of the people who live there. The site is situated on agricultural land with banana cultivation, on dark grey-brown clay-loams, on a north-facing slope.

KOKS35	031°17.589 E
Karangira	00°35.914 S
16 October 2007	1250m

High-density scatter of slag, tuyére and pottery over an area of about 5000m^2, mainly consisting of piles of slag moved from field clearance, including very large slag blocks measuring up to 1m in diameter. Site is situated on agricultural land (millet, rice and banana) on a south-facing slope and dark yellowish brown sandy-clay-loams.

KOKS36	031°17.876 E
Karangira	00°35.715 S
16 October 2007	1257m

High-density scatter of slag blocks in the road – possibly used as part of the road construction, so not recommended for excavation. Site is situated over an area of about 10m^2 on a gentle, east-facing slope on silty-loam.

KOKS37	031°19.605 E
Katwe	00°34.862 S
16 October 2007	1287m

Medium-density scatter of slag and tuyére over an area of about 2500m^2. There is also another circular depression of about 5m in diameter with some archaeological material coming out. Site is situated on cultivated land (cassava) on a south-facing slope, on dark grey soils.

KOKS38	031°19.419 E
Kisamole	00°44.839 S
18 October 2007	1285m

Low to medium-density scatter of slag and pottery (KPR, TGR) in road and surrounding compound stretching for about 35m. Site is situated on a moderate, west-facing hillside, sloping between Nabuzosi Hill and Kibale River, on light greyish brown sandy silts.

KOKS39	031°21.559 E
Lwenkakala	00°45.358 S
18 October 2007	1276m

High-density scatter of slag, tuyére and pottery (KPR, CWR) over an area of about 1250m². Collection of about 100 large slag blocks on a hillside in agricultural land belonging to Lwenkakala Primary School. Site is situated on a moderate southwest-facing slope, on light greyish brown sandy silt.

KOKS40	031°22.247 E
Kyawanyana	00°47.753 S
19 October 2007	1238m

Low-density scatter of pottery (KPR, TGR) and slag over an area of about 225m². Slag has mostly been collected from field clearance. Site is situated on agricultural land (banana) on a southwest-facing slope and brown silts and has been quite heavily disturbed by cultivation.

KOKS41	031°22.248 E
Kifamba	00°47.752 S
22 October 2007	1238m

Low-density scatter of slag and tuyére over an area of about 100m². Site is situated on agricultural land on a southeast-facing slope on brown clay, and has been highly disturbed by cultivation.

KOKS42	031°27.737 E
Kibwera	00°45.069 S
22 October 2007	1260m

High-density scatter of slag, tuyére and bones over an area of about 1750m². Site is being damaged by water erosion, banana cultivation and excavation for commercial purposes, so has low potential for excavation. Site is situated on dark grey soils.

KOKS43	031°26.439 E
Kasalu	00°44.684 S
22 October 2007	1281m

High-density scatter of slag over an area of about 3500m². Many slag blocks have apparently been removed for building. Site is situated on a northwest-facing hillside used for grazing on dark grey soils.

KOKS44 031°22.619 E
Kamukalo 00°45.463 S
24 October 2007 1280m

High-density slag scatter, mostly medium sized slag blocks, on a south-facing hillside that also has exposures of iron-rich deposits. The area is used for grazing and the soils are light brown. The archaeological deposits occur over an area of about 3500m^2.

Masindi Survey

MAS1 031°30.887 E
Kisalizi ("pruning knife") 01°30.784 N
7 November 2007 1231m

Medium-density scatter of slag and pottery (KPR) over an area of about 300m^2, in paths, surrounding agricultural fields and compounds. Nearby house has medium sized blocks of slag in foundations and surrounding grassland – approximately 20-30 visible. Site is situated on a very gentle slope to the northeast on dark brown silty clays.

MAS2 031°30.404 E
Kisalizi ("pruning knife") 01°31.152 N
7 November 2007 1136m

High-density scatter of slag and tuyére over an area of about 100m^2. Some pottery (KPR). Lots of broken slag fragments in densely planted maize field with some accompanying tuyére, but very difficult to see very much due to mature maize. Site is situated on a gentle slope to the southwest, on dark reddish-brown soils.

MAS3 031°30.433 E
Kisalizi ("pruning knife") 01°31.009 N
7 November 2007 1128m

Mining site consisting of a single 'enambo' in a maize field. Pit is about 1m in diameter with vertical sides and has been filled in to about 1m from the top. The man who showed us (who is about 40 years old) said that his grandfather found it there when they moved to the land, so it is probably at least 100 years old. Site is situated on a west-southwest-facing slope leading down to a swamp on reddish brown soils.

MAS4	031°34.799 E
Kijugusi ("place of bellowing")	01°29.729 N
8 November 2007	1126m

Small, localised high-density scatter of slag fragments and pottery (KPR) in an area of about 10m^2 in a compound garden. An elderly man told us that there were a lot of slag blocks here at one time, but that they were all removed by prisoners (from the prison nearby) for building. Site is situated on a moderate northwest-facing slope, on mid reddish brown soils.

MAS5	031°34.632 E
Kisambo	01°29.362 N
8 November 2007	1125m

Low-density slag scatter collected from field clearance. Not recommended for excavation. Site is situated on agricultural land, on a northwest-facing slope on medium reddish brown soils.

MAS6	031°35.300 E
Kinanebuhere	01°27.660 N
8 November 2007	1081m

High-density scatter of slag and tuyére over an area of about 200m^2. Some pottery (KPR). Consists of piles of slag blocks and fragments collected during field clearance. Site is situated on overgrown agricultural land (maize and scrub) on a ridge-top on dark reddish-brown soils.

MAS7	031°34.856 E
Kisambo	01°29.571 N
8 November 2007	1136m

Medium-density slag scatter over an area of approximately 200m^2. Mainly small slag fragments collected from field clearance. Site is situated on agricultural land (sweet potatoes) on a northwest-facing slope, on mid reddish brown soils.

MAS8	031°34.386 E
Kisambo	01°29.646 N
8 November 2007	1133m

High-density scatter of slag and pottery (undecorated), consisting mainly of a large pile of slag blocks, about 2m high and containing an estimated 300 blocks. Site is situated over an area of about 50m^2 and is on a northwest-facing slope behind a compound house on greyish brown soils.

MAS9	031°37.143 E
Kyababande	01°32.627 N
8 November 2007	1124m

Medium-density scatter of slag and pottery (KPR) over an area of about 50m². Site is situated on a very gentle south-southeast-facing slope between Murro Hill and a small lake, and on mid-brown soils. Low potential for excavation.

MAS10	031°37.437 E
Kyabyebuga	01°30.412 N
9 November 2007	1106m

High-density slag and KPR pottery scatter over an area of 25m². Mainly slag fragments but some slag blocks as well (maybe up to 100). Slag blocks unusually small (20-25cm in diameter). Site is situated in bushy, overgrown land around a maize plantation, on flat land and dark reddish-brown soils.

MAS11	031°37.527 E
Byebega	01°30.218 N
9 November 2007	1104m

Medium-density slag scatter over an area of about 400m², although there are several other areas in Byebega with similar piles from slag clearance.

MAS12	031°37.929 E
Byebega	01°30.064 N
9 November 2007	1099m

Low to medium-density scatter of slag fragments collected from fields whilst digging over an area of about 5000m². Low potential for excavation. Site is situated on flat, agricultural land on dark brown soils.

MAS13	031°38.666 E
Byebega kyamuhuma	01°29.713 N
9 November 2007	1090m

Medium-density scatter of slag blocks and slag fragments over an area of about 200m². Other nearby piles of slag, but we were refused access to see them. This whole area appears rich in smelting waste. Site is situated within an area of banana cultivation, on a gentle south-southeast slope on mid brown soils.

MAS14	031°40.020 E
Kinyamasasa	01°34.986 N
9 November 2007	1151m

Low-density scatter of slag over an area of about 400m². A small collection of slag blocks in a potato field. Site is situated on highly disturbed, agricultural land on a southeast-facing slope on brown clayish soils.

MAS15	031°39.152 E
Kiharara ("large locust")	01°31.015 N
9 November 2007	1110m

Medium-density scatter of slag over an area of about 2000m². Heavily cultivated, so highly disturbed and not recommended for excavation. Site is on a southeast-facing slope, on loose brown soils.

MAS16	031°33.602 E
Kisagura	01°35.593 N
12 November 2007	1151m

Medium-density slag scatter over an area of about 2000m². Consists of several large slag blocks at edges of fields due to field clearance and in house foundations, but also slag fragments across compound. Very little pottery, none decorated, and no tuyére. Site is situated on a gentle northeast-facing slope on light brown soils next to a sugar-cane plantation.

MAS17	031°33.159 E
Bwenamira	01°38.204 N
12 November 2007	1114m

Medium to high-density scatter of slag over an area of about 100m². Highly disturbed due to sugar-cane plantation and use of tractors. Consists of scatters of broken slag fragments across surface, and barely any pottery. Site is on a northeast-facing slope on dark reddish brown soils.

MAS18	031°33.096 E
Bwenamira	01°37.928 N
12 November 2007	1110m

Medium-density slag and pottery (KPR) scatter over an area of about 2000m² consisting of a large pile of slag blocks (between 50 and 60) in a very overgrown area behind compound. Site is situated on a southeast-facing slope, on light orange, rocky murram-like gravels and stones.

MAS19 031°32.826 E
Bwenamira 3 01°38.428 N
12 November 2007 1128m

High-density slag scatter over an area of about 150m^2, consisting of a couple of piles of slag blocks from field clearance. Very overgrown, so difficult to see pottery and other archaeological remains on the ground. Site is situated on a northeast-facing slope, directly below a ridge-top on dark brown soils in a scrubby area at edge of cultivated land.

MAS20 031°31.753 E
Nybugoma 01°38.986 N
12 November 2007 1128m

High-density scatter of slag and tuyére over an area of about 300m^2. Site is under a thick sugar-cane plantation, and has been highly disturbed by the tractors there. Site is situated on flat land, and on dark brown loamy soils.

MAS21 031°31.509 E
Nyabigoma 01°39.481 N
12 November 2007 1089m

Medium to high-density scatter of slag over an area of about 700m^2. Some large slag blocks, but mostly broken slag fragments collected whilst digging. Site is situated on a gentle, north-facing slope on dark brown soils.

MAS22 No GPS reading
Katanjojo
12 November 2007

Low-density scatter of slag fragments in road over an area of about 50m^2. Low potential for excavation. Site is on a northwest-facing slope on compact mid-orangey brown soils.

MAS23 031°27.475 E
Katogo 1 01°37.627 N
13 November 2007 1147m

Medium-density scatter of slag, tuyére and pottery (KPR) over an area of about 100m x 100m. Site is within a field of cassava with frequent small broken slag fragments. Very occasional pot and tuyére. Highly disturbed, so very little potential for excavation. Site is on a south-south-east-facing slope coming down from Mybederi (or Mwoba?) Hill, on mid-brown soils.

MAS24	031°27.418 E
Katogo 2	01°38.058 N
13 November 2007	1158m

Low to medium-density slag and tuyére scatter over an area of about $800m^2$, plus a small pile of slag fragments collected from field clearance. Site is situated on an east-facing slope in bushy land next to agricultural land (cassava and ground nuts) on dark brown loamy soils.

MAS25	031°27.104 E
Katogo 2	01°38.141 N
13 November 2007	1141m

Moderate-density scatter of slag and tuyére over an area of about $600m^2$, including a small pile from field clearance. Not recommended for excavation, and few remains and highly disturbed. Site is situated within a patch of scrubland next to agricultural land (ground nuts) on a moderate southwest-facing slope that leads down to Budongo Forest Reserve (c.100m away).

MAS26	031°29.280 E
Nyantonzi	01°38.704 N
13 November 2007	1130m

High-density scatter of slag and tuyére over an area of about 100m x 50m. Remains have been revealed after being churned up by tractor, so very highly disturbed, and not recommended for excavation. Site is on flat land within a sugar-cane plantation, on dark brown soils.

MAS27	031°29.461 E
Siba	01°39.510 N
13 November 2007	1072m

Low-density scatter of slag and pottery over an area of about $400m^2$, mostly small fragments, sometimes larger ones. Site is situated on agricultural land on a small ridge top, and on mid-brown soils.

MAS28	031°29.733 E
Siba	01°39.691 N
13 November 2007	1071m

High-density scatter of tuyére and slag spread over an area of about $100m^2$. Site is on an east-facing slope on agricultural land (ground nuts) and dark grey soils. Highly disturbed by cultivation.

MAS29 No GPS reading
Rambisi
13 November 2007

Low-density scatter of small slag fragments in small road next to agricultural land, over an area of about 20m. Site is situated near the top of a small hill, on the northwest-facing slope and is on mid orangey brown soils.

MAS30	031°40.612 E
Rukondawa	01°36.813 N
14 November 2007	1071m

High-density scatter of slag and pottery (KPR and CWR) over an area of about 240m^2, including a pile of larger slag fragments in middle of field of peas. Site is situated on a northwest-facing slope on mid reddish brown soils.

MAS31	031°38.598 E
Ikoba	01°35.655 N
14 November 2007	1169m

Medium-density scatter of slag fragments and slag blocks over an area of about 50m x 20m. Some pottery (CWR). Site is said to have been the place of smelting about 80 years ago; the ore was called *matale* and was brought from Budongo. Site is situated in agricultural land, on a north-facing slope and on mid brown soils.

MAS32	031°38.318 E
Ikoba	01°35.556 N
14 November 2007	1137m

Medium-density slag and pottery scatter over an area of about 200m^2. Site is situated on a north-northwest-facing slope on dark brown soils in agricultural land.

MAS33	031°36.849 E
Kisonga (“top of tree or plant”)	01°34.938 N
14 November 2007	1145m

Very high-density scatter of slag blocks and slag fragments, plus some pottery, burnt ceramic (possible furnace wall?) and tuyére, scattered throughout maize fields over an area of about 400m^2. Site is situated on a southwest-facing slope, coming down from Sogyo Hill on very dark grey (charcoal rich?) soils, contrasting strongly with the surrounding reddish brown soils. Could be excavation, though it is somewhat disturbed by the cultivation. Ore said to have come from Sogyo Hill, on the surface.

MAS34	031°36.856 E
Kisonga ("top of tree or plant")	01°34.828 N
14 November 2007	1133m

Medium-density slag blocks, slag fragments, tuyére and pottery (KPR, CWR) scatter over an area of about 100m^2, close to MAS33. Site is situated on flat, agricultural land (potatoes) on dark reddish brown soils.

MAS35	031°36.823 E
Kisonga ("top of tree or plant")	01°34.718 N
14 November 2007	1128m

Medium-density scatter of slag blocks collected into two piles, measuring about 10m long and 2m wide, over an area of about 120m^2. Site is situated on agricultural land surrounded by bush, on dark reddish brown soils.

MAS36	031°39.679 E
Karijubu	01°40.402 N
14 November 2007	1111m

Medium-density scatter of slag and pottery (KPR) spread over about 10m. It has been collected from field clearance from nearby agricultural land. Site is situated on a northwest-facing slope, on dark orange-brown soils.

MAS37	031°39.919 E
Kina	01°36.046 N
15 November 2007	1184m

Low-density scatter of slag collected from nearby fields over about 10m. Site is situated on a west-facing slope, on mid-orange brown soils.

MAS38	031°41.382 E
Kachinda	01°36.214 N
15 November 2007	1160m

Medium-density scatter of slag, tuyére and pottery (KPR) over an area of about 250m^2. Low potential for excavation due to high levels of agricultural disturbance. Site is situated opposite a sugar-cane plantation, and is on a southwest-facing slope on silty brown soils.

MAS39	031°42.285 E
Kinlambulu	01°35.805 N
15 November 2007	1116m

Medium-density scatter of slag, pottery (KPR) and tuyére over an area spanning about 100-200m. Site is situated within a compound and surrounding agricultural land, on a southeast-facing slope and on medium brown soils.

MAS40	031°42.940 E
Butebe	01°37.110 N
15 November 2007	1115m

Low-density scatter of slag and tuyére over an area of about 20m x 20m, in the front courtyard of an illegal drinking den. Some pottery (KPR). Site is situated on beaten earth floors on mid orange-brown soils.

MAS41	031°42.892 E
Butobe	01°37.225 N
15 November 2007	1119m

High-density scatter of slag, possible pieces of furnace wall or burnt ceramic and pottery over an area of about 400m². Consists mainly of three slag piles and slag fragments. Site is situated on agricultural land, on a southeast-facing slope.

MAS42	031°41.448 E
Rwijere	01°39.144 N
16 November 2007	1163m

Medium-density scatter of slag and pottery (KPR) over an area of about 350m², including a pile of about 20 slag blocks covered under thick vegetation. Site is situated on agricultural land plus the surrounding overgrown bush-land, on a north-facing slope coming down from Rwijire Hill, on reddish brown soils.

MAS43	031°40.664 E
Kibwama	01°38.910 N
11 November 2007	1170m

High-density scatter of pottery (KPR) and slag over an area of about 100m². Some medium slag blocks, but mainly slag fragments in a patch of dark greyish brown soils surrounded by reddish soils. Well defined site, which could be excavated, but highly disturbed by tractor use. Site is situated on a northwest-facing slope in agricultural land dedicated to sugarcane.

MAS44	031°40.059 E
Kibyama/Nyabisense	01°39.009 N
16 November 2007	1121m

High-density scatter of slag and pottery (KPR, CWR) over an area of about 200m². Approximately 60 blocks of slag (there used to be more, but many have been removed). Very distinctive dark greyish brown soils, in contrast to surrounding brown soils, makes it easy to distinguish the site. Site is situated in sugar-cane plantation on flat land to the northwest of the hills of Nyakahara and Bugakama. Ore is said to have been gathered from the surface (i.e. not from dug pits) of the western side of Nyakahara Hill.

MAS45 031°41.718 E
Chikaranga 01°36.885 N
16 November 2007 1134m

Medium-density scatter of slag and pottery (KPR, CWR) over an area of about 25m^2, including a collection of slag blocks. Site is situated in agricultural/bush land, on a north-facing slope, on mid reddish brown soils. Highly disturbed due to cultivation.

MAS46 031°41.591 E
Chikaranga 01°36.888 N
16 November 2007 1177m

High-density scatter of slag and pottery (KPR, CWR) over an area of about 50m^2. Small fragments of slag collected from surrounding fields and piled up. Site is situated on agricultural land (bananas), on a north-facing slope with reddish-brown soils.

MAS47 031°41.541 E
Chikaranga 01°36.835 N
16 November 2007 1192m

High-density scatter of slag and pottery (KPR, CWR) over an area of about 200m^2. High concentration of slag on dark reddish-brown soils – could be worth excavating. Site is on a north-facing slope.

MAS48 No GPS reading
Kinjanga
16 November 2007

Very low-density slag scatter over about 225m^2 in highly disturbed agricultural land on a southwest-facing slope on brown, gravely soils. Low potential for excavation.

MAS49 No GPS reading
Kisengya
16 November 2007

Low-density scatter of slag over an area of about 150m^2. Some pottery (CWR). Site is situated on agricultural land on a north-facing slope, on brown loamy soils. Low potential for excavation.

MAS50 031°43.709 E
Kisengya 01°39.477 N
16 November 2007 1189m

Medium-density scatter of slag and pottery (CWR) over about 20m. Site is situated on a southeast-facing slope, on mid orangey-brown soils. Possible furnace base near house. Area is open and relatively undisturbed.

MAS51	031°38.925 E
Kibwona	01°39.696 N
19 November 2007	1192m

Medium to high-density scatter of slag over an area of about 150m². Site is situated on a gentle northeast-facing slope on dark brown, very humic soils.

MAS52	031°39.037 E
Kibwona	01°39.725 N
19 November 2007	1154m

Medium-density scatter of slag and pottery (KPR) over an area of about 50m² – the house neighbouring MAS51. Lots of large slag blocks (c.30) within a compound garden. Site is situated on a gentle northeast-facing slope, on dark brown soils.

MAS53	031°38.680 E
Kibwona	01°40.096 N
19 November 2007	1145m

Medium-density scatter of slag and pottery (KPR) over an area of about 50m². Medium-sized slag blocks, which have been moved in order to be used as land demarcations. Site is situated on flat, agricultural land on dark brown soils.

MAS54	031°39.018 E
Kibwona	01°40.267 N
19 November 2007	1103m

High-density scatter of slag and pottery (red painted) over an area of about 50m². The site is situated on agricultural land (maize), on an east-facing slope on dark grey soils.

MAS55	031°39.302 E
Kabalye	01°41.113 N
19 November 2007	1103m

High-density scatter of slag fragments and slag blocks over an area of about 200m². Very overgrown, so difficult to see the ground very well. Site is situated about 100m to the south of Kabalye Primary School, in a very overgrown area behind agricultural land on very dark black, charcoal rich soils.

MAS56	031°39.195 E
Kabalye	01°41.035 N
19 November 2007	1107m

Medium-density scatter of slag and pottery (KPR) over an area of about 500m². Scatter is in road and neighbouring agricultural fields, on mid reddish brown soils. Highly disturbed, so not recommended for excavation.

MAS57	031°40.366 E
Kirima	01°42.068 N
19 November 2007	1121m

High-density scatter of slag and pottery (CWR, KPR) over an area of about 600m^2. Slag fragments and a lot of pottery throughout very dark brown soils, which are surrounded by reddish brown soils – distinct soil change demarcating a well defined area associated with the archaeological remains. Some large slag blocks in compounds downslope and in the road. Site is situated on agricultural land (bananas) on a gentle southeast-facing slope.

MAS58	031°42.268 E
Kihuuba	01°43.656 N
19 November 2007	1145m

High-density scatter of slag and pottery (KPR, CWR) over an area of about 400m^2. Site is situated in a field of sweet potatoes, and includes both slag fragments and small slag blocks. Site is on a very slight southwest-facing slope on mid-reddish brown soils.

MAS59	No GPS reading
Kihuuba	
19 November 2007	

Medium-density scatter of slag and pottery (KPR) over an area of about 300m^2. It is said that the grandfather of the person who owns this land was smelting until 1972. A few complete slag blocks are also around. Site is situated in a compound on a south-facing slope.

MAS60	031°43.754 E
Kyema	01°43.737 N
26 November 2007	1153m

Low-density scatter of slag and tuyére, collected from field clearance. Some pottery (KPR). Site is situated in agricultural land on a southwest-facing slope on dark brown, loose soils.

MAS61	031°43.304 E
Masindi Town	01°41.055 N
26 November 2007	1147m

Smelting site. Medium-density scatter of slag and pottery (KPR) over an area of about 200m^2, plus the remains of a furnace base, in path leading between Asaba School and Traveller's Corner Restaurant. Furnace is about 40/45cm in diameter, with a wall about 5cm thick. Site is situated on southeast-facing slope on orange murram gravels. Some medium sized slag blocks also in path.

Appendix D

Informal interviews and conversations with informants, interpreted by Elijah Kisembo

Informal interview with Kabajugusi Keloi, whose father was a smelter, Ruhoko, Kyenjojo

21 July 2007

00°37.829N
030°35.817E
1358m

Kabajugusi's father was a smelter in Ruhoko, Mwenge in Kyenjojo district. She was given the name Kabajugusi, as she was born at a time when her father was busy smelting. As a young girl, she assisted him in his work, and as such she retains some memories of the processes that were undertaken. Her father had probably learnt his trade from his friends, as her grandfather hadn't been a smelter. When asked how old she was, she replied that she was married aged 13 in the 1920s, so was likely to have been born at the beginning of last century [perhaps around 1912 as an average estimation?] making her around 95 years old now. Her husband had died in 1990 aged 81. She was able to describe the mining and smelting processes, and also to answer specific questions that we had concerning iron production in the area.

She first described that *obutale* (iron ore) was mined from 20 feet down, from, for example, Kilembe mine. Men mined the ore, and women could help to carry it back. It was recognised as being a potentially dangerous task. Whether it was dug horizontally or vertically, it didn't matter – the seam was just followed. She was unaware of any ritual associations with the mining, although she suggested that sacrifices may have been made, but as she was young and female, she wouldn't have necessarily known.

The *obutale*, once collected, was crushed or pounded and then dried. It was then kept in the house until required by the smelting. After the ore had been collected, they went to the forest to look for the trees used to make charcoal for smelting. They were called *emihakwa*, which was a very hard wood, and which was good for long burning. Her father had been in charge of all aspects of collecting ore, collecting charcoal and smelting. If charcoal was needed, an entire day would be given to collecting and preparing it; if ore was needed, the same would happen for that. Smelting occurred every day, throughout the year, unless the ore or the charcoal ran out – there were no special seasons or months for smelting.

A pit was then dug for the furnace and a fire was started there. Smelting was undertaken within her father's compound – and the place of the furnace was called *isasa* [forge]. There was no fence to separate the furnace and work area from the rest of the compound. Children weren't discouraged from being around. The furnace was approximately one meter in diameter, and it wasn't too deep, so that it was easy to remove the slag and ore. There was no lining to the furnace pit, but the hole was cleaned. There was no superstructure, which allowed for iron to be levered out with a stick as it formed, as well as allowing for further iron ore to be added as it progressed. No plants were used to pack the furnace, and the same furnace was used again and again.

One tuyére led from one set of bellows into the furnace pit. The tuyéres and pipe (bellows?) were bought from pottery specialists, and the tuyéres were made from a mixture of sand and clay. [It wasn't clear, but it appears that the clay was the same as that used for making household pots, and that the tuyéres may have been bought unfired.] The bellows were completed using a dried and softened sheep skin, with the hair removed.

Charcoal was piled on one side of the furnace, and the dried *obutale* on the other. Some charcoal was swept into the furnace, then ore, then charcoal and so on. The furnace produced no flames, but burnt like a charcoal stove. Sometimes the furnace was burning for two days, continuously smelting. The bellowing made a lot of noise – you could here it from the surrounding hills.

She remembers there often being a line of people queuing up to take over the bellowing, when the person in front grew tired. There was always a lot of meat around, so that when people got hungry they could easily eat. This slaughter of animals attracted people to come and help with the smelt, and there were often a lot of people around. No payment was made to those who came to help with the smelt, but they were often smiths who were going to buy the iron – they weren't paid, but were given meat to eat. There were no restrictions that she knew of concerning women being involved, or being present. She didn't think there were particular associations with smelting and reproduction, and smelting was not considered to affect fertility. She herself was sometimes put in charge of preparing the ore, and she sometimes took part in the bellowing.

Immediately as the iron formed, the iron was taken from the furnace, removed from the slag, and hammered to remove any slag pieces and inclusions. The combined mass of iron and slag was the size of a football, and after they were separated, the resultant iron was split and divided up among those who wanted to buy some. Sometimes however, if the ore was bad, it would produce only a little iron.

People came from far extremes of the Toro kingdom to buy the iron from here. Her father also smithed the iron if required. It occurred in the same place as the smelting. If someone wanted raw iron they were given raw iron, if they wanted smithed items, he was able to make them for them. Items produced from his iron were *muhoro* (scythes), *kisarizo* (bill hooks), knives for cutting, sewing needles for mats, *mpindo* for making baskets, hoes, *mulinga* (bangles – often sold to spirit mediums), spears and *kihoso* (tools for digging holes).

Spears were given to the king. She wasn't sure whether these were sold, or given as taxes, but she thought that kingdom didn't have any controls over iron production – although it encouraged it. There were few smelters in the local area, but lots of smiths. To the best of her knowledge, all the smelters used the same process, as she has described. It was easy to access the raw materials, as there was more communal land in those days.

She didn't know about associations with clans and smelting, as in those days movement was very limited, and it wasn't fully known what was happening in the surrounding areas. Also, people were few. However, her father was of the Babopi clan (she, or rather her husband, was of the Bahinda, or Monkey, clan). She also didn't know how long smelting had been practiced in the area, but knew that it stopped with the arrival of European materials, which destroyed the market. By the time Kasagama died, local smelting had already ceased. During the time of Kabalega, smelting was still happening.

Informal interview with Ezekiel Kaheru at Kisojo, near Matiri, Kyenjojo

23 July 2007

00°31.992N
030°43.764E
1340m

Smelting occurred all around Kisojo, but he thought that it would be difficult to relocate – some locations were in the bush, some have now been covered.

One skin was used to cover both bellows bowls, but only one bellows and one tuyére were used in the smelt.

Omuseke [bamboo] was the name of the iron rod used to send the iron ore into the furnace.

The furnace was one foot deep, 60/70cm in diameter. There was no superstructure, only a shelter built over it.

The ore would "melt like water". The iron was dragged out of the furnace using the *omuseke*. The slag would collect by the tuyère. The iron, which is melted and soft, could be moulded using the *omuseke* as it was dragged out of the furnace, into a circular or linear shape.

The same furnace was used over and over again.

The bellows and the tuyères were fired, and were made by the smelter.

When people would go to extract the ore, they couldn't sleep on beds – they had to sleep directly on the floor. They also couldn't sleep with their wives. There had to be nine days of sleeping alone and two days of sleeping 'down'. There was a special place in the family compound where these people would go to sleep during this time, so that they would be away from people and temptation.

Only mature women could go to the place where they mined. Children weren't allowed to go there in case they didn't understand the rituals. If women went there menstruating, they could spoil the ore and make things go wrong, so it was a taboo for women to be there.

There was only one clan who smelted – you couldn't employ people from outside – the clan wanted to retain the knowledge within their own places. There were four smelting clans in the area: the Bangeri (who smelted around Kisojo); the Abasara (who smelted around Ihamba); the Bahinda (who smelted around Kagorra); and the Basita (who smelted around Rugombe).

Spears were given to the king (Okwikya). It was a privilege to give to the king.

Smelting ended around 1891?

Smelting occurred in family homes/compounds.

Comments during survey from old man at Mirongo I, Kyenjojo

19 July 2007

Remembered where his grandfather used to smelt on his land up to 100 years ago. [Slag blocks and smelting remains are apparent]

Member of the Enyonyi clan (bird totem). Believed that clan didn't matter when smelting [*enyonyi* is not one of the usual clans associated with smelting]

Comments made by Kamulindwa Johanna from Kihura, Kyenjojo

23 July 2007
Interviewed at Kampadwe

Informant was in his late 80s, he led us to an area with mining and smelting remains. He had witnessed smelting in this place when he was very young.

Women and small children were not allowed near the smelting. Women could threaten the smelters, if they had had sex the night before. Women also couldn't carry the ore. The smelters were not allowed to sleep with their wife when going to get the ore and when smelting.

Bangeri clan all used to be smelters.

They used to give iron spears as gifts to the king. Taxes were paid in cowries.

The furnace was a pit in the ground with no superstructure. Two bellows were used, and one ore, called *obutale*. No sacrifices were made for the furnace.

Smelting occurred throughout the year, whenever it was needed.

Smelters were also smiths, and smelting and smithing happened in the same place.

Comments made by informant at Kyarusura, Kyenjojo

23 July 2007

This site was a smithing site until more recently, but was a smelting site before that. The informant's father (Brasiyo Kabaruri) was a smith; her grandfather (Bitamazire) was a smelter.

They were both of the Bangeri clan (*Amasomi* [Amasumi?] *ekobe* totem). These were the ones who had the knowledge of smelting.

Other relatives of hers (of the same clan) smithed at Kitabona.

Comments during survey from two elderly men at Nyarukoma, near Matiri, Kyenjojo

24 July 2007
Elijah Kisembo

The fathers' of these men were smelters in Kipepa. They said that there was not much slag around this place (Matiri) and that smelting was instead concentrated in other areas.

Bahinda and Bacwa clans also used to smelt. Smelting was not monopolised by one clan, the knowledge of smelting could sometimes be transmitted through friendship to a person who is not of the same clan.

Women were not discouraged or not allowed to visit the smelting place, but the knowledge was mainly held by men. It was only the limited knowledge held by women that made them not participate in the production of iron.

Comments from shop-owner at Rugombe, Kyenjojo

27 July 2007

Smelting probably must have ended between 1912 to 1922. Smelting used to take place in locations with a good water supply.

There was a lot of specialisation in the process of iron production, some focused on mining, and/or carrying iron ore and others had different roles.

Comments made by informant at Katebe, Kyenjojo (KYS67)

1 August 2007

Some local men told us that they had been told stories about smelting happening at this place for a long time.

One said that his grandmother, who died in 1999 aged 108, also didn't remember herself smelting happening at the site, but that she had been told stories about it too.

Comments made by informant near Mabale, Kyenjojo (KYS74)

3 August 2007

An old lady led us to this site – she had wanted to cultivate this area of land but there were too many slag blocks and she couldn't dig it so it's been left fallow.

She remembers smelting when she was younger, around the age of 6 (she's around 70 now), in Mabale, further north along the main road.

She said that people used to smelt far away to lessen the burden of carrying the ore, and they instead just smithed close to the houses.

Comments made by informant near Mirongo, Kyenjojo (KYS98)

8th and 9th August 2007

During survey, we encountered a group of two elderly women and one elderly man on the road outside their compound, just to the south of Mirongo trading centre.

One old lady led us to her compound, where she had some slag. The old man remembered smelting (his father was a smelter), but he was reluctant to talk to us – many of the slag blocks had been taken from here to be used in the tombs of his parents, I think he was nervous that our activity would disturb these tombs. He believed smelting continued until 1912.

We went past the same place the next day, and saw the old man by the road again, but this time without the ladies. That day he was eager to speak to us (it seems that the women who were with him were discouraging him from talking). So he spoke to us about smelting in the area. He remembered smelting from when he was younger, and took us to see the place where smelting used to happen.

He told us that smelting and smithing would always happen in open places so that people passing by could offer advice about what they were making – smelting and smithing happened at the same time, and were done by the same people. Smelting happened all through the year, as long as there was ore.

The smelting furnace was a circular furnace with bellows, with a pile of iron ore and a pile of charcoal. There was a fire lit in the furnace, but water was kept by the side to keep the flames under control. The furnace was just a pit in the ground, not built up.

Some would even smelt on the road, but no-one would steal as they could have a curse put on them.

Smelters were respected as almost all society life depended on them – iron hoes, pangas, even marriage. Special status and respect – families were happy to give their daughters to smelters as they'd be sure to get iron into the future. Well respected – someone could even give two hoes in exchange for a woman.

Men weren't allowed to sleep with women during the smelt. Smelters were able to put curses on people by hitting a piece of their iron and speaking a curse.

Not every smelter was obliged to give to the king, as he had his own smelters – around Katoke [place name meaning "small twins"? Katoke is a sub county in Mwenge, further north along the road to Hoima. Katoke is also the name of the junction town immediately to the west of Iboroga sub-county HQ. The excavated site of Kyakaturi is in Katoke] – who used to make spears for the king. The chiefs to the king always chose the best smelters and smiths to make iron and objects for the king – not related to clan. Within every clan there was at least one person who smelts, even Bagaya-Nyakurungu. Omlebeke were the clan of the soldiers of the king.

Smelting to get iron stopped with Kabalega, but smithing continued.
The man told us that he had always lived in this place (Mirongo), even when there were elephants here! He professed to be over 100 years old, and had children who were in their 80s. He said that he was baptised in 1920, when he was already an adult. Bakitimbe Kayijanabwo.

Comments made by informant at Cikandwa, Kyenjojo (KYS101)

8th August 2007

The owner of the land at this site (slag and tuyère scatter) said that his family (Abamoki clan) were smelters and then smiths for many generations back.

Comments made by informant near Luteebe, Kooki (KOKS6)

3rd October 2007

Magurumali was once the Kabaka's smith, making knives etc. Wasn't chosen on basis of clan, but on expertise.

Comments made by informants at Kiwesi, Kooki (KOKS17)

5th October 2007

The people here say there is a long tradition of smelting and smithing here, since perhaps the eighteenth century. The whole family [at the compound where the features were later excavated] are said to have links with smelting and smithing. They migrated here from Bunyoro in around the eighteenth century; some are still in Bunyoro.

Comments made by informant near Kyabyebuga, Masindi (MAS10)

9th November 2007

A man called Alex Nyakojo remembered witnessing smelting when he was about 8 years old. He was about 88 years old at time of interview.

Masindi was a centre for smelting, people used to come from all other areas of Bunyoro to get iron (e.g. Bugangaizi, of Kibale district). He couldn't pinpoint the areas in Masindi where smelting happened, as it happened all over. People could come from all over (even Basingo), learn the trade and then return with the knowledge.

Ore was mined from the surface, they didn't need to dig much, although in other areas they had to dig *enambo*. They used only the black ore, (from the surface), very difficult to break: 'female' stones. They didn't use the 'male' stones, which were white.

The furnace was a pit dug into the ground (about 3 feet deep, 3 feet wide), plastered with clay (from rivers, normal clay). It was not built up [i.e. no superstructure]. 3 pairs of bellows were used, and a whole sack of charcoal. Smelting had to happen during a full moon. If there wasn't a full moon there would be problems.

The Basingo Bakalari clan specialised in smelting. No women were involved, but he didn't know why – suggested just 'convention'. Smelting happened all year around, 'an occupation'.

As smelters were still servants of the king, on land that belonged to the king, they'd sometimes give a selection of items to the king (e.g. three-pointed spears), and during 'exhibitions' would display their smelting skills to the king. The king had special smelters, chosen dependent on their skills.

Appendix E

Macroscopic tuyère descriptions: Kyakaturi

Context	Colour	Inclusions	Thickness (cm)	Internal diam. (cm)	Notes
79	Light brown	Quartz	1.04	4	vitrified
80	Beige brown	Grog, quartz	1.30	4	
80	Light grey	Grog, quartz	0.83	4	vitrified
80	Light grey	Grog, quartz	0.83	4	vitrified
80	Light beige	Grog, quartz	1.67	5	flared end
80	Light grey	Grog, quartz	1.06	4	
80	Dark grey	Quartz	1.03	4	
80	Dark grey	Grog, quartz	0.86	4	
80	Light grey	Quartz	1.07	5	flared end
80	Dark grey	Quartz	1.08	5	
80	Dark grey	Grog, quartz	1.01	4	
80	Dark grey	Grog, quartz	1.09	4	
80	Dark grey	Quartz	0.83	5	
80	Light grey	Grog, quartz	0.84	5	
80	Light grey	Grog, quartz	0.82	4	
80	Light grey	Grog, quartz	0.76	4	
80	Beige grey	Quartz	1.02	5	
80	Light grey	Grog, quartz	0.76	4	
80	Dark grey	Quartz	0.74	4	
80	Greenish grey	Quartz	0.71	4	
80	Greyish green	Grog, quartz	1.02		
80	Light brown	Quartz	0.89	3	vitrified
80	Greyish green	Quartz	0.81	2	
80	Beige grey	Grog, quartz	0.89	3	
80	Greenish grey	Quartz	0.87	4	
80	Dark grey	Grog, quartz	0.74	2	
80	Greenish grey	Quartz	0.78	3	
80	Light grey	Quartz	0.89	3	
80	Light brown	Quartz	1.14	3	vitrified
80	Beige brown	Quartz	1.07	4	
80	Light brown	Grog, quartz	1.01	4	
80	Beige brown	Grog, quartz	0.99	3	
80	Dark grey	Grog, quartz	1.04	5	
80	Orange brown	Grog, quartz	1.04	3	
80	Light brown	Quartz	0.77	3	vitrified
80	Orange brown	Quartz	1.07	4	
surface	Yellowish white	Grog, quartz	0.90	5	flared end
surface	Grey	Grog, quartz	1.03	5	vitrified
surface	Yellowish white	Grog, quartz	0.90	5	
surface	Beige, grey	Quartz	0.88	5	vitrified, blackened inner
surface	Greyish brown	Grog, quartz	0.98	5	blackened inner
surface	Yellowish grey	Grog, quartz	1.44	5	vitrified
surface	Yellowish grey	Grog, quartz	0.97	4	
		Averages:	0.96	4	

Appendix F

Unnormalised PED-XRF data: Kyakaturi

Table F.1 Ceramics

22/1/10		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	Rb_2O ppm	SrO ppm	ZrO2 ppm	Nb_2O_5 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Vitrified quartzite	1	0.40	/	1.28	99.35	0.03	0.03	0.21	0.16	0.06	/	0.01	0.07	6.21	114	7	37	18	7	29	67	43	142	42	38	69	107.87
	2	0.43	/	1.30	99.37	0.05	0.03	0.21	0.16	0.06	/	0.01	0.07	6.21	118	8	35	19	7	29	68	44	137	33	/	44	107.95
	3	0.52	/	1.28	99.47	0.04	0.03	0.21	0.16	0.07	/	0.01	0.07	6.21	104	8	33	19	7	30	60	47	139	33	44	79	108.12
Tuyère A	1	0.44	0.13	18.24	73.95	/	0.05	1.77	0.14	1.03	/	0.01	0.02	2.49	48	29	33	91	75	49	685	53	543	108	189	121	98.47
	2	/	/	18.25	73.82	/	0.05	1.76	0.14	1.03	/	0.01	0.02	2.49	50	27	34	95	76	48	705	46	542	101	191	130	97.78
	3	0.36	0.15	18.25	73.82	/	0.05	1.76	0.14	1.03	/	0.01	0.02	2.50	41	28	32	93	76	48	712	50	543	129	189	148	98.30
Tuyère B	1	/	0.27	20.10	67.29	/	0.05	1.81	0.23	1.13	0.00	0.01	0.02	2.53	51	42	45	57	90	59	757	46	820	201	270	239	93.70
	2	0.30	0.38	20.26	67.59	/	0.06	1.83	0.23	1.12	0.00	0.01	0.02	2.53	52	42	41	57	91	59	771	51	814	173	271	182	94.59
	3	0.38	0.35	20.27	67.67	/	0.06	1.83	0.22	1.13	0.00	0.01	0.02	2.54	51	43	42	58	91	59	758	50	817	189	279	217	94.74
Furnace Wall	1	0.20	0.03	25.24	35.66	0.10	0.05	0.16	0.05	1.81	0.06	0.02	0.38	18.46	334	53	175	120	26	2	605	29	234	79	252	107	82.42
	2	0.18	0.05	25.47	35.88	0.11	0.07	0.16	0.05	1.81	0.06	0.02	0.38	18.58	345	57	186	120	26	2	587	34	248	121	270	51	83.02
	3	0.04	/	25.41	35.88	0.08	0.08	0.16	0.05	1.81	0.06	0.02	0.38	18.64	341	59	182	118	26	2	614	35	230	100	232	125	82.82
Surface pot	1	0.05	0.18	20.40	67.29	0.04	0.07	1.87	0.15	0.87	/	0.01	0.03	2.58	57	38	59	45	116	29	553	48	422	112	184	151	93.70
	2	0.12	0.18	20.28	67.16	0.01	0.07	1.86	0.16	0.87	/	0.01	0.03	2.58	51	39	60	50	115	30	546	46	422	155	222	180	93.51
	3	0.44	0.26	20.42	67.46	0.02	0.07	1.86	0.16	0.87	/	0.01	0.03	2.59	41	36	63	47	116	29	560	47	419	102	174	/	94.35

Table F.2 Ore

25/11/09		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	Co_3O_4 ppm	CuO ppm	ZnO ppm	SrO ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Ore (from furnace)	1	/	/	3.15	3.65	1.38	0.07	0.07	0.05	0.16	0.04	0.11	0.48	88.75	800	76	258	126	783	456	2430	1147	1037	98.63
	2	/	/	3.11	3.72	1.38	0.07	0.07	0.05	0.16	0.04	0.11	0.48	88.53	890	83	248	122	812	447	2260	1055	1051	98.41
	3	/	/	3.17	3.69	1.37	0.07	0.07	0.05	0.16	0.04	0.11	0.48	89.20	1004	89	258	129	737	446	2264	1026	1002	99.10

Table F.3 Slag

25/11/09		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO ppm	Co_3O_4 ppm	CuO ppm	ZnO ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Furnace slag M	1	0.21	0.41	7.00	33.39	1.63	0.05	1.41	4.16	0.37	0.04	0.11	0.98	58.63	719	363	95	753	89	538	3439	1164	834	836	109.28
	2	0.27	0.40	6.84	33.33	1.61	0.05	1.39	4.12	0.37	0.04	0.11	0.97	58.09	603	333	92	749	90	519	3435	1215	897	833	108.47
	3	0.29	0.40	6.74	33.17	1.60	0.06	1.40	4.08	0.37	0.04	0.11	0.96	57.69	582	341	87	748	87	512	3402	1236	910	686	107.76
Furnace slag B	1	0.31	0.32	5.05	33.27	1.67	0.07	1.16	2.41	0.25	0.04	0.17	0.94	62.45	1103	425	97	512	63	380	2599	934	665	560	108.83
	2	0.19	0.27	4.97	33.16	1.65	0.07	1.15	2.41	0.24	0.04	0.17	0.94	62.28	754	432	96	507	59	390	2579	870	690	665	108.24
	3	0.46	0.22	5.00	33.13	1.68	0.07	1.14	2.39	0.24	0.04	0.16	0.93	62.15	818	436	103	506	62	412	2568	906	692	566	108.33
Slag 1 M	1	0.12	0.18	8.08	33.31	1.51	0.06	1.09	1.19	0.55	0.05	0.08	0.58	60.75	1124	449	69	298	78	656	1158	561	984	126	108.09
	2	0.17	0.16	8.08	33.36	1.51	0.06	1.09	1.20	0.54	0.05	0.08	0.58	60.87	536	451	70	305	86	661	1104	550	958	90	108.23
	3	0.49	0.24	8.21	33.58	1.52	0.06	1.10	1.22	0.55	0.05	0.08	0.58	61.26	1017	441	73	308	76	653	1138	566	925	127	109.47
Slag 2 M	1	0.23	0.36	9.50	36.98	1.30	0.06	1.88	3.02	0.55	0.05	0.14	0.70	55.37	962	262	56	329	49	361	1478	265	365	/	110.54
	2	0.32	0.29	9.40	36.78	1.28	0.06	1.86	3.01	0.55	0.05	0.13	0.69	55.31	966	266	53	326	46	364	1463	270	355	92	110.15
	3	0.34	0.38	9.54	37.19	1.28	0.06	1.90	3.02	0.56	0.05	0.14	0.70	55.90	959	246	55	338	74	328	1499	300	366	120	111.48
Slag 6 T	1	0.20	0.38	7.38	29.97	1.92	0.11	1.55	3.94	0.39	0.05	0.17	1.07	62.37	653	320	48	616	73	557	2259	551	778	264	110.11
	2	0.19	0.30	7.29	29.98	1.90	0.11	1.56	3.94	0.38	0.05	0.17	1.07	62.37	768	329	45	618	72	546	2237	557	727	456	109.95
	3	0.21	0.37	7.37	30.11	1.96	0.11	1.56	3.96	0.38	0.05	0.17	1.08	62.56	771	319	52	622	73	549	2249	546	754	372	110.51
Slag 6 B	1	0.30	0.39	8.90	34.94	1.51	0.04	1.51	4.26	0.46	0.03	0.09	0.94	55.19	580	257	59	578	72	506	2138	409	638	337	109.12
	2	0.29	0.37	8.73	34.68	1.49	0.04	1.49	4.24	0.45	0.03	0.09	0.93	54.37	673	259	59	562	60	520	2111	436	608	334	107.78
	3	0.28	0.35	8.89	35.36	1.53	0.04	1.53	4.31	0.45	0.03	0.09	0.95	55.40	659	236	58	577	61	524	2147	466	612	208	109.76
Slag 7 B	1	0.33	0.18	8.29	33.49	1.95	0.09	1.74	3.10	0.45	0.03	0.08	1.83	55.68	413	190	53	449	67	499	2693	389	667	205	107.80
	2	0.14	0.24	8.35	33.94	1.98	0.09	1.76	3.15	0.46	0.04	0.08	1.85	56.44	415	187	64	456	67	519	2720	437	625	281	109.09
	3	0.22	0.18	8.26	33.70	1.96	0.09	1.75	3.14	0.46	0.03	0.08	1.84	56.10	387	190	61	455	73	532	2709	432	661	155	108.37
Slag 8 M	1	0.46	0.27	8.36	32.58	1.62	0.08	1.70	2.36	0.41	0.05	0.08	0.96	58.05	757	289	46	446	75	593	2575	527	894	399	107.63
	2	0.29	0.25	8.38	32.50	1.65	0.08	1.69	2.34	0.41	0.05	0.08	0.96	57.81	677	302	53	434	75	588	2571	581	940	202	107.15
	3	0.24	0.22	8.35	32.56	1.65	0.08	1.67	2.33	0.40	0.05	0.08	0.95	57.76	770	317	49	436	74	592	2580	541	898	417	107.01
Slag 9 M	1	0.05	0.24	7.31	33.08	1.87	0.09	1.58	2.11	0.44	0.04	0.08	0.68	59.66	614	426	68	389	79	555	1782	563	981	168	107.79
	2	0.20	0.23	7.30	32.96	1.93	0.09	1.60	2.13	0.44	0.04	0.08	0.69	59.87	880	448	78	396	80	581	1777	588	1005	267	108.16
	3	0.43	0.23	7.38	33.08	1.89	0.09	1.60	2.12	0.44	0.04	0.08	0.69	60.14	719	429	65	395	79	575	1777	547	963	384	108.79
Slag 10 T	1	0.31	0.28	8.78	33.14	1.61	0.10	1.90	3.28	0.61	0.05	0.11	1.23	57.70	851	242	45	382	55	476	1992	404	523	320	109.62
	2	0.23	0.28	8.74	33.29	1.63	0.10	1.89	3.28	0.61	0.05	0.11	1.23	58.07	661	243	40	385	59	476	2002	342	453	408	110.01
	3	0.24	0.25	8.76	33.15	1.63	0.10	1.88	3.27	0.61	0.05	0.11	1.22	57.74	608	236	40	386	59	449	1957	375	484	222	109.48
Slag 10 M	1	0.44	0.26	6.82	27.79	1.70	0.08	1.21	2.45	0.43	0.06	0.14	1.50	66.71	676	424	61	249	40	368	1314	258	205	/	109.94
	2	0.18	0.31	6.97	28.00	1.68	0.08	1.22	2.48	0.44	0.07	0.14	1.51	67.01	666	419	53	251	43	311	1252	202	302	/	110.43
	3	/	0.29	6.81	27.43	1.64	0.08	1.19	2.43	0.43	0.06	0.14	1.47	65.31	816	421	59	242	42	325	1267	203	300	/	107.63
Slag 10 B	1	0.25	0.35	8.55	35.65	1.22	0.06	1.53	2.89	0.53	0.05	0.13	0.79	57.65	787	324	71	326	49	370	1578	328	429	79	110.08
	2	0.22	0.34	8.44	35.44	1.19	0.06	1.51	2.88	0.52	0.05	0.13	0.79	57.37	762	319	62	328	46	357	1518	274	334	/	109.34
	3	0.30	0.35	8.48	35.53	1.21	0.05	1.52	2.89	0.52	0.05	0.13	0.79	57.39	666	334	76	325	52	327	1572	298	364	/	109.62
Slag 11 M	1	0.24	0.41	8.44	31.79	1.49	0.06	1.54	2.26	0.46	0.08	0.19	1.08	60.88	701	237	39	209	40	288	1395	168	340	/	109.26
	2	0.17	0.37	8.60	32.12	1.49	0.06	1.56	2.27	0.46	0.08	0.19	1.09	61.27	773	260	44	212	39	298	1424	244	341	/	110.10
	3	0.20	0.29	8.59	31.59	1.47	0.06	1.55	2.25	0.46	0.08	0.19	1.08	60.35	774	242	42	206	37	314	1395	223	335	/	108.52
Slag 16 M	1	/	0.22	9.65	42.55	1.41	0.08	1.96	4.07	0.48	0.05	0.12	0.98	46.48	475	156	53	555	69	503	3323	326	461	284	108.68
	2	0.18	0.35	9.78	42.76	1.42	0.08	1.99	4.10	0.48	0.05	0.12	0.99	46.64	666	156	48	558	72	473	3372	332	443	377	109.58
	3	0.26	0.33	9.71	42.39	1.39	0.08	1.95	4.07	0.48	0.05	0.12	0.98	46.56	391	149	56	557	73	466	3361	382	470	421	108.99

Appendix G

Macroscopic tuyère descriptions: Mirongo

Context	Colour	Inclusions	Thickness (cm)	Internal diam. (cm)	Notes
47	Light grey	Fine quartz	1.06	5	
47	Light grey	Quartz, grog	1.1	4	
47	Mid orange	Quartz, coarse grog	0.86		
47	Mid brown	Coarse to fine quartz	1.41	5	Vitrified
47	Mid brown	Fine quartz	1.43	6	Vitrified
47	Light grey	Occasional quartz, grog	1.06	4	
47	Light to mid grey	Fine quartz, coarse pot	1.01	3	
48	Mid orange	Quartz, coarse grog	1.25	4	
48	Mid orange	Fine quartz, coarse grog	0.86	5	
48	Mid orange	Fine quartz, coarse grog	1.18	6	
48	Mid orange	Fine quartz, coarse grog	0.77		
48	Mid orange	Coarse quartz, coarse grog	1.16	5	
48	Mid orange	Fine quartz, grog	1.08	4	
48	Mid orange to mid grey	Fine quartz, coarse grog	1.34	4	
48	Light orange	Fine quartz	1.04	5	
48	Light grey	Grog	1.06	6	
48	Mid orange	Quartz, coarse grog	0.93	5	
48	Mid grey	Quartz, grog	1.09	3	
48	Mid grey	Quartz, grog	1.28	6	
48	Light orange	Quartz, coarse grog	1.17	6	
48	Light orange	Quartz, coarse grog	0.86		
48	Dark orange	Quartz, grog	1.14	4	
48	Mid brown to grey	Quartz, very coarse grog	1.45	6	
48	Mid brown	Quartz	1.19	5	
48	Grey to light orange	Grog	1.11	6	
48	Orange to mid brown	Quartz, coarse grog	1.09	7	
48	Light orange	Quartz, grog	1.23	4	
48	Mid brown	Quartz, slag	1.83		
48	Mid brown	Quartz, grog	4.03	6	Vitrified
48	Light brown	Fine quartz, grog	1.06		
48	Light orange to dark grey	Quartz	1.1	6	
48	Light to mid orange	Quartz, coarse grog	1.36	5	
48	Grey to mid orange	Quartz, coarse grog	1.15		
48	Mid orange	Grog	0.8		
48	Light orange	Quartz, very coarse grog	1.09		
48	Mid brown	Quartz	2.35	5	Vitrified
52	Light orange	Quartz, grog	0.9	5	Vitrified
52	Mid brown	Quartz, fine grog	1.36	4	
52	Light to mid grey	Quartz, coarse grog	1.15	4	
52	Mid brown	Quartz, coarse grog	1.3	6	
52	Grey	Quartz, occasional grog	1.07	5	
52	Light orange to dark grey	Quartz	1.07	5	
63	Mid grey	Quartz, occasional fine grog	1.03	5	
63	Mid to light grey	Quartz, grog	1.4	5	
63	Light grey	Occassional quartz	0.99	4	
65	Light orange to mid grey	Occasional quartz	1.54	5	
65	Light orange	Quartz, grog	0.88		
		Averages:	**1.2**	**4.9**	

Appendix H

Unnormalised PED-XRF data: Mirongo

Table H.1 Ceramics

22/1/10		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	Co_3O_4 ppm	NiO ppm	CuO ppm	ZnO ppm	Rb_2O ppm	SrO ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Furnace Wall	1	0.31	0.09	24.72	39.12	0.23	0.04	0.26	0.14	1.48	0.05	0.02	0.21	16.52	316	51	163	77	32	35	542	183	219	269	93	83.40
	2	0.29	0.09	24.71	39.25	0.22	0.05	0.26	0.14	1.48	0.04	0.02	0.21	16.53	294	51	161	77	33	33	527	178	268	323	177	83.50
	3	0.20	0.11	24.81	39.36	0.21	0.05	0.26	0.14	1.49	0.05	0.02	0.21	16.63	275	58	149	75	32	34	535	179	237	278	116	83.74
Tuyère A	1	0.36	0.29	19.66	68.57	0.02	0.04	0.66	0.22	1.37	0.00	0.02	0.02	3.82	46	44	118	72	40	33	552	433	61	86	96	95.22
	2	0.36	0.30	19.73	68.63	0.01	0.04	0.66	0.23	1.38	0.00	0.02	0.02	3.83	64	42	110	72	41	34	561	431	60	84	113	95.38
	3	0.33	0.30	19.76	68.69	0.01	0.04	0.66	0.22	1.38	0.01	0.02	0.02	3.83	49	44	116	72	41	34	554	429	39	73	76	95.43
Tuyère B	1	0.30	0.26	18.84	76.23	/	0.03	0.61	0.14	1.49	0.01	0.02	0.03	4.19	76	41	140	77	32	20	601	203	107	143	131	102.31
	2	/	0.07	18.87	76.01	/	0.03	0.61	0.14	1.50	0.01	0.02	0.03	4.19	54	44	139	74	32	20	574	199	109	129	97	101.64
	3	0.41	0.28	18.89	76.29	/	0.03	0.61	0.14	1.50	0.01	0.02	0.03	4.20	65	43	140	76	32	20	595	214	141	172	116	102.58
Test Pit A Pot	1	0.11	0.14	20.66	64.64	0.03	0.12	0.29	0.52	3.01	0.03	0.03	0.07	5.29	98	48	78	80	12	34	993	268	66	101	/	95.12
	2	/	0.08	20.62	64.30	0.04	0.12	0.29	0.52	3.01	0.03	0.03	0.07	5.26	140	45	79	80	12	35	978	270	71	113	70	94.55
	3	0.37	0.15	20.70	64.41	0.04	0.12	0.29	0.52	3.01	0.03	0.03	0.07	5.30	88	50	80	81	12	34	989	274	69	113	70	95.22
Test Pit B Pot	1	0.22	0.61	22.92	56.25	0.08	0.06	1.20	0.92	1.67	0.04	0.08	0.04	6.85	123	105	74	69	111	74	519	1116	18	/	96	91.16
	2	/	0.53	22.85	56.32	0.08	0.06	1.20	0.92	1.67	0.04	0.08	0.04	6.85	105	110	80	68	111	75	533	1162	25	61	103	90.88
	3	/	0.52	22.98	56.59	0.08	0.06	1.20	0.93	1.67	0.03	0.08	0.04	6.88	113	106	75	66	111	75	517	1153	39	61	77	91.30

Table H.2 Slag

11/1/10		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	Co_3O_4 ppm	NiO ppm	CuO ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Trench 3 Slag 1 M	1	0.10	0.57	8.15	34.04	0.93	0.15	1.26	1.89	/	0.08	0.07	8.45	49.73	/	17	630	490	59	381	11466	523	741	942	106.95
	2	0.27	0.51	8.08	33.97	0.91	0.15	1.23	1.88	/	0.07	0.08	8.49	49.64	/	10	656	480	60	415	11399	512	752	999	106.79
	3	0.16	0.46	8.30	34.14	0.92	0.15	1.28	1.86	/	0.07	0.08	8.52	49.79	/	21	631	477	60	358	11489	512	774	892	107.24
Cluster 1 Slag 1 M	1	0.16	0.19	6.02	31.67	2.27	0.12	1.59	1.21	0.42	0.04	0.10	1.75	59.29	412	/	205	288	56	680	1537	588	542	156	105.29
	2	0.20	0.22	6.12	31.59	2.24	0.12	1.58	1.20	0.42	0.04	0.10	1.75	59.10	498	/	179	291	59	648	1521	595	585	212	105.14
	3	0.34	0.25	6.00	31.25	2.24	0.12	1.56	1.19	0.42	0.04	0.10	1.73	58.59	515	/	168	283	56	660	1504	560	583	426	104.31
Cluster 1 Slag 3 M	1	/	0.09	5.75	19.29	1.80	0.33	1.31	1.10	0.38	0.08	0.29	0.86	73.30	1109	/	660	220	55	649	566	452	583	141	105.03
	2	/	0.14	5.85	19.50	1.84	0.33	1.32	1.12	0.39	0.08	0.30	0.87	74.50	1243	/	688	224	56	662	569	476	548	/	106.69
	3	/	0.16	5.88	19.24	1.83	0.33	1.31	1.11	0.38	0.08	0.29	0.86	73.83	1130	/	650	214	51	647	569	437	563	159	105.77
Cluster 1 Slag 5 M	1	/	/	6.54	20.31	1.75	0.24	1.26	1.28	0.42	0.03	0.13	3.77	66.05	1014	192	925	372	64	1066	3593	1007	743	797	102.75
	2	0.09	/	6.74	20.41	1.77	0.25	1.28	1.31	0.43	0.03	0.13	3.81	66.76	1082	177	901	386	67	1106	3581	997	791	797	103.99
	3	0.21	/	6.76	20.75	1.81	0.25	1.28	1.31	0.43	0.03	0.13	3.86	66.98	977	181	943	380	66	1066	3579	950	743	846	104.78
Cluster 1 Slag 6 B	1	0.17	0.29	7.02	30.87	1.97	0.13	1.33	1.49	0.55	0.04	0.09	1.74	57.17	556	/	202	386	97	833	1472	737	690	406	103.39
	2	0.41	0.39	7.06	30.74	1.97	0.12	1.32	1.49	0.55	0.04	0.09	1.74	57.20	316	/	212	394	99	775	1467	810	672	559	103.65
	3	0.36	0.25	7.00	30.74	1.95	0.13	1.32	1.48	0.55	0.04	0.09	1.73	56.71	500	/	199	377	99	803	1454	763	672	334	102.87
Cluster 2 Slag 1 M	1	0.39	1.53	7.89	35.07	2.22	0.24	2.57	4.11	/	0.05	0.08	13.57	38.70	/	22	201	1149	89	625	11019	1773	1169	1558	108.18
	2	0.30	1.75	8.00	35.98	2.29	0.25	2.60	4.14	/	0.04	0.08	12.80	39.09	/	/	190	1142	86	620	10952	1744	1120	1433	109.06
	3	0.07	1.57	7.92	35.21	2.24	0.24	2.59	4.14	/	0.05	0.08	13.61	38.62	/	10	185	1153	89	591	11052	1711	1066	1423	108.06
Cluster 3 Slag 1 B	1	/	0.24	9.94	31.68	0.99	0.09	0.96	1.70	/	/	0.13	11.93	44.56	/	36	126	334	73	490	14660	408	367	921	103.96
	2	/	0.16	9.93	31.40	0.96	0.09	0.97	1.69	/	/	0.13	12.46	44.34	/	26	128	342	71	446	14559	380	330	942	103.87
	3	/	0.30	9.94	31.65	0.95	0.09	0.95	1.70	/	/	0.14	12.63	44.40	/	37	120	343	78	455	14648	373	340	759	104.46
Cluster 3 Slag 2 M	1	0.22	2.09	7.65	37.59	1.97	0.21	2.33	5.87	/	/	0.08	10.36	37.78	/	11	337	1157	77	522	10201	1290	963	1035	107.70
	2	0.27	2.01	7.77	37.49	1.95	0.21	2.30	5.92	/	0.01	0.08	10.41	37.74	/	27	349	1160	79	515	10189	1241	934	1195	107.73
	3	0.23	2.07	7.82	37.77	1.96	0.21	2.31	5.97	/	0.01	0.08	10.43	38.00	/	19	332	1170	78	490	10237	1306	1011	1269	108.43
Cluster 3 Slag 4 B	1	0.07	0.52	8.01	31.33	1.10	0.08	1.87	2.50	/	/	0.07	12.81	41.54	/	12	66	258	109	373	37347	1876	1313	3441	104.38
	2	0.32	0.53	7.81	31.39	1.12	0.08	1.89	2.50	/	/	0.07	13.09	41.69	/	/	50	260	113	350	37347	1872	1335	3363	104.95
	3	0.10	0.50	7.73	30.43	1.09	0.07	1.82	2.44	/	/	0.07	12.20	41.90	/	12	78	261	112	350	38173	3395	3204	6799	103.58
Cluster 3 Slag 5 M	1	0.19	0.64	11.13	28.20	0.93	0.07	1.25	2.05	/	/	0.21	12.09	44.70	/	23	100	196	93	292	28303	1336	991	2695	104.87
	2	0.27	0.70	11.21	28.41	0.95	0.07	1.26	2.03	/	/	0.21	12.28	44.78	/	17	115	204	97	294	28672	1345	950	2294	105.57
	3	0.09	0.71	11.20	28.63	0.93	0.08	1.24	2.03	/	0.03	0.21	12.25	44.76	/	16	98	196	98	280	28638	1313	969	2293	105.54
Furnace slag 1 B	1	0.20	0.19	5.74	21.80	2.36	0.12	1.31	1.93	0.41	0.06	0.10	2.94	64.26	311	/	262	555	75	1505	3333	1910	1208	871	102.43
	2	0.34	0.18	5.71	21.65	2.32	0.13	1.30	1.93	0.40	0.06	0.09	2.91	63.72	264	/	263	563	73	1491	3385	1947	1176	844	101.75
	3	/	0.17	5.70	21.56	2.32	0.13	1.31	1.94	0.40	0.06	0.10	2.91	63.66	270	/	278	554	75	1487	3324	2015	1235	859	101.26
Furnace slag 1 M	1	0.31	0.14	4.82	17.29	1.95	0.24	0.86	1.21	0.35	0.06	0.11	3.14	69.52	395	/	396	432	56	1339	3664	1092	709	622	100.87
	2	/	0.10	4.79	17.35	1.95	0.25	0.87	1.23	0.35	0.06	0.11	3.11	69.55	506	/	378	430	52	1282	3734	1146	765	640	100.61
	3	0.07	0.11	4.73	17.29	1.89	0.24	0.86	1.21	0.35	0.06	0.11	3.09	69.10	452	/	383	427	56	1289	3705	1167	774	623	100.00
Furnace slag 1 T	1	0.21	0.16	5.50	19.25	2.23	0.26	0.97	1.38	0.39	0.07	0.09	3.10	68.01	317	/	299	491	62	1406	3823	1368	934	687	102.56
	2	0.10	0.16	5.51	19.02	2.16	0.26	0.95	1.37	0.39	0.07	0.09	3.10	67.46	392	/	335	484	65	1464	3811	1427	936	687	101.60
	3	/	0.18	5.65	19.18	2.21	0.26	0.96	1.39	0.39	0.06	0.09	3.12	67.82	394	/	340	486	64	1388	3839	1376	945	783	102.27
Furnace slag 2 M	1	0.29	0.33	6.13	28.99	2.57	0.15	1.21	2.86	0.47	0.04	0.06	3.12	58.83	420	/	291	678	83	1441	4333	1859	1076	879	106.16
	2	0.23	0.30	5.96	28.96	2.52	0.15	1.23	2.87	0.48	0.05	0.06	3.12	58.65	350	/	268	674	77	1354	4329	1834	1065	957	105.66
	3	0.26	0.33	6.01	28.51	2.52	0.15	1.23	2.87	0.48	0.04	0.06	3.11	58.66	305	/	279	669	79	1433	4359	1905	1135	903	105.35

Appendix I

PCA report: Mirongo (90.02% of variance explained in total)

Table I.1 Principal component scores

	PC1	PC2	PC3	PC4	PC5
Tr3 S1 M	0.21	-0.78	-1.03	-0.27	0.02
C1 S1 M	-0.56	0.01	-0.55	-1.06	-0.47
C1 S3 M	-1.40	-0.85	-0.58	0.26	2.54
C1 S5 M	-0.99	-0.58	-0.08	2.94	-1.32
C1 S6 B	-0.34	0.10	0.03	-0.99	-1.09
C2 S1 M	1.18	1.34	-0.89	0.30	0.72
C3 S1 B	0.58	-1.59	-0.74	-0.85	-1.29
C3 S2 M	1.27	1.26	-1.64	0.66	0.17
C3 S4 B	1.70	-0.29	2.23	0.57	0.44
C3 S5 M	1.09	-1.59	0.52	-0.22	0.60
FS1 B	-0.55	1.03	1.03	-0.23	0.14
FS1 M	-1.01	0.21	0.42	-0.36	0.24
FS1 T	-0.85	0.53	0.68	-0.44	0.03
FS2 M	-0.32	1.18	0.60	-0.33	-0.73

Table I.2 Loading vector values

Original	Loading Vectors				
Variables	1	2	3	4	5
MgO	.71	.43	-.46	.11	.20
Al2O3	.71	-.58	-.13	-.04	-.13
SiO2	.77	.09	-.40	-.22	-.22
P2O5	-.50	.81	.03	-.05	-.04
K2O	.62	.49	-.26	.25	.24
CaO	.67	.56	-.34	.18	.08
TiO2	-.85	.26	.23	-.07	-.20
V2O5	-.74	.22	-.07	-.17	.39
Cr2O3	-.32	-.59	-.12	.09	.58
MnO	.92	-.21	-.07	.10	.02
FeO	-.96	-.01	.25	.03	.08
Co3O4	-.84	-.10	-.01	.38	.15
NiO	-.14	-.27	-.11	.84	-.42
CuO	-.59	-.13	-.30	.65	.06
SrO	.34	.78	-.44	.14	.00
Y2O3	.69	.03	.49	-.01	-.14
ZrO2	-.67	.52	.35	.01	-.20
BaO	.81	-.37	.42	.08	.12
La2O3	.38	.54	.70	.18	.09
CeO2	.49	.36	.71	.23	.19
Nd2O3	.74	-.13	.59	.20	.12

Table I.3 Total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.54	45.45	45.45	9.54	45.45	45.45
2	3.80	18.12	63.56	3.80	18.12	63.56
3	2.88	13.72	77.28	2.88	13.72	77.28
4	1.63	7.76	85.05	1.63	7.76	85.05
5	1.05	4.98	90.02	1.05	4.98	90.02
6	.86	4.07	94.10			
7	.61	2.92	97.01			
8	.28	1.34	98.35			
9	.19	.93	99.28			
10	.08	.38	99.66			
11	.05	.23	99.89			
12	.02	.10	99.99			
13	.00	.01	100.00			
14	.00	.00	100.00			
15	.00	.00	100.00			
16	.00	.00	100.00			
17	.00	.00	100.00			
18	.00	.00	100.00			
19	.00	.00	100.00			
20	.00	.00	100.00			
21	.00	.00	100.00			

Appendix J

Macroscopic tuyère descriptions: Rugombe

Context	Colour	Inclusions	Thickness (cm)	Internal diam. (cm)	Notes
6	Brown	Small grog	1.76	/	
8	Beige	Frequent quartz, grog	1.43	4	
12	Dark grey	Frequent quartz, grog	0.86	2	
12	Light beige	Frequent quartz, grog	1.09	3	
12	Dark beige	Small quartz	0.77	5	
12	Greyish brown	Small quartz and grog	1.1	6	
12	Dark beige	Few small quartz	0.73	5	Slight flaring
15	Light beige	Some large grog	1.01	6	Vitrification
15	Dark beige	Frequent grog	1.03	4	Vitrification
15	Beige	Frequent grog, quartz	1.01	3	
15	Brownish grey	Frequent grog, quartz	1.26	3	
15	Dark grey	Frequent grog, quartz	1.46	4	
15	Dark brownish grey	Frequent grog, quartz	1.28	3	
15	Beige	Few grog	1.01	4	
15	Dark grey	Few grog, quartz	1.12	4	
15	Brownish grey	Few grog, quartz	0.83	3	Vitrification
15	Dark brownish grey	Few grog, quartz	1.17	5	
15	Dark beige	Frequent grog, quartz	0.96	5	
15	Brownish grey	Few small quartz	1.08	/	
15	Beige	Few small quartz	0.9	/	
15	Beige	Few small quartz	1.11	4	
15	Dark beige	Frequent large grog	1.18	5	
15	Dark beige	Frequent grog	1.17	4	
15	Brownish grey	Frequent grog, quartz	0.86	6	
15	Dark grey	Few small quartz	1.37	3	Vitrification
15	Beige	Frequent grog	1.08	3	
15	Dark grey	Few grog, small quartz	1.29	4	
15	Dark grey	Few grog, small quartz	1.06	5	Vitrification
15	Dark grey	Few small quartz	1.06	3	Vitrification
15	Beige	Few grog	1.04	3	
15	Dark grey	Few small quartz	0.96	4	
15	Dark grey	Few grog, quartz	1.41	4	
15	Dark grey	Mica, few grog	1.06	4	Vitrification
15	Dark grey	Few large quartz	1.18	3	Vitrification
15	Dark grey	Few large quartz	1.18	3	Vitrification
15	Beige	Few small quartz, grog	1.14	3	
15	Dark grey	Frequent small quartz	1.1	3	Vitrification
15	/	/	0.88	2	Vitrification
16	Dark grey	Few small quartz	0.92	3	Vitrification
17	Dark brown	Small grog, quartz	1.24	4	
		Averages:	**1.1**	**3.8**	

Appendix K

Unnormalised PED-XRF data: Rugombe

Table K.1 Ceramics

21/1/10		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	NiO	CuO	ZnO	Rb_2O	SrO	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	PbO	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Furnace Wall	1	0.20	0.18	24.19	46.16	0.19	0.05	0.59	0.11	1.15	0.02	0.03	0.07	9.94	127	47	56	113	59	23	621	405	198	453	90	11	83.10
	2	/	0.07	24.21	46.35	0.16	0.06	0.59	0.11	1.16	0.02	0.03	0.07	9.96	116	47	55	112	59	23	622	406	203	475	118	13	83.00
	3	0.20	0.16	24.36	46.64	0.19	0.07	0.60	0.12	1.17	0.02	0.03	0.07	9.95	219	41	59	114	59	24	636	396	168	427	116	13	83.79
Tuyère (016)	1	0.30	0.41	22.29	72.26	/	0.03	0.65	0.39	1.70	0.01	0.02	0.05	3.66	81	62	54	63	30	44	754	448	181	274	221	42	102.00
	2	0.35	0.43	22.28	72.61	/	0.03	0.65	0.39	1.70	0.01	0.02	0.05	3.68	81	63	55	65	31	44	769	434	169	248	147	45	102.41
	3	0.41	0.41	22.24	72.49	/	0.03	0.65	0.39	1.70	0.01	0.02	0.05	3.67	91	62	50	65	29	44	766	429	154	245	130	44	102.27
Tuyère (017)	1	0.27	0.27	24.65	59.66	0.02	0.04	0.37	0.21	1.24	/	0.02	0.01	1.78	39	35	69	31	40	37	639	505	161	186	138	55	88.73
	2	0.24	0.27	24.71	59.78	0.03	0.04	0.38	0.21	1.25	0.00	0.02	0.01	1.79	50	33	71	34	40	37	659	520	214	245	226	56	88.93
	3	/	0.20	24.67	59.67	0.02	0.04	0.38	0.21	1.24	/	0.02	0.01	1.78	39	34	72	33	40	37	642	515	203	234	207	54	88.45
Pot (008)	1	/	0.22	24.83	57.95	0.16	0.05	1.36	0.27	1.29	0.01	0.02	0.02	3.51	66	47	64	64	84	55	685	412	145	227	160	36	89.89
	2	0.33	0.32	25.00	58.35	0.17	0.05	1.36	0.28	1.29	0.01	0.02	0.02	3.52	60	44	59	65	83	55	695	424	156	247	152	38	90.93
	3	0.37	0.30	24.85	58.25	0.17	0.05	1.36	0.28	1.29	0.01	0.02	0.02	3.52	65	42	58	64	84	55	703	418	166	241	180	36	90.70
Pot (012)	1	0.04	0.28	19.88	62.51	0.05	0.06	0.34	0.70	2.16	0.03	0.03	0.05	5.87	112	72	82	70	29	88	741	362	72	118	86	7	92.17
	2	0.05	0.28	20.14	63.15	0.04	0.06	0.35	0.70	2.18	0.03	0.03	0.05	5.89	147	71	87	68	29	89	757	363	72	108	79	6	93.13
	3	0.44	0.36	20.22	63.26	0.04	0.06	0.35	0.70	2.18	0.03	0.03	0.05	5.93	118	70	86	73	30	90	733	379	85	133	/	7	93.83

Table K.2 Ore

12/1/10		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	CuO	ZnO	SeO_2	SrO	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Ore A	1	/	/	2.00	2.89	0.85	0.10	0.01	0.05	0.21	0.08	0.05	0.29	84.50	981	392	58	363	55	446	85	424	231	333	91.37
	2	0.06	/	1.90	2.87	0.85	0.10	0.01	0.05	0.21	0.08	0.05	0.29	84.79	806	368	54	363	57	484	88	443	256	226	91.58
	3	/	/	1.99	2.83	0.86	0.11	0.01	0.05	0.21	0.08	0.05	0.29	84.62	846	405	52	344	56	433	88	470	279	163	91.40
Ore B	1	0.06	/	0.55	38.12	0.16	0.03	/	0.02	0.07	0.01	0.02	0.48	64.29	1123	33	54	/	98	215	189	626	452	219	104.11
	2	/	/	0.52	38.47	0.16	0.03	/	0.02	0.07	0.01	0.02	0.48	64.91	1054	25	59	/	98	229	195	661	404	207	104.98
	3	0.15	/	0.52	38.15	0.15	0.03	/	0.02	0.07	0.01	0.02	0.48	64.56	712	59	57	/	96	217	193	677	425	160	104.42

Table K.3 Slag

8/12/09		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	CuO	ZnO	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Cluster 1 Slag 1 M	1	0.38	0.24	7.36	28.60	2.47	0.20	1.08	1.86	0.55	0.06	0.11	0.96	60.33	1015	156	11	860	103	1683	789	1023	1020	780	104.94
	2	0.47	0.22	7.26	28.19	2.45	0.19	1.06	1.83	0.54	0.06	0.10	0.95	59.74	654	136	/	847	101	1622	780	1098	1110	529	103.75
	3	0.19	0.24	7.36	28.03	2.45	0.20	1.05	1.83	0.55	0.06	0.10	0.94	59.70	713	172	7	850	105	1592	751	1031	1039	637	103.39
Cluster 1 Slag 2 M	1	0.19	0.05	5.27	20.53	4.05	0.16	0.09	1.18	0.33	0.05	0.05	1.22	73.77	723	368	27	1741	112	1022	1712	2638	2011	1312	108.11
	2	0.27	0.06	5.33	20.81	4.07	0.16	0.09	1.21	0.33	0.05	0.06	1.24	74.59	680	366	31	1777	120	1015	1667	2607	2002	1200	109.40
	3	0.37	/	5.25	20.54	4.02	0.16	0.09	1.20	0.33	0.04	0.06	1.23	74.38	973	354	32	1785	113	1016	1657	2577	2005	1362	108.85
Cluster 1 Slag 3 T	1	0.17	/	4.94	12.64	2.45	0.24	0.16	0.63	0.22	0.09	0.11	2.86	83.57	523	910	28	986	107	1043	4211	1476	1453	1069	109.24
	2	0.31	/	4.99	13.05	2.52	0.24	0.17	0.65	0.22	0.09	0.11	2.94	85.48	698	941	25	1014	111	1003	4275	1465	1495	888	111.96
	3	0.13	/	4.95	12.75	2.48	0.24	0.16	0.64	0.22	0.09	0.11	2.90	84.17	529	902	25	974	119	1041	4203	1383	1395	1056	110.01
Cluster 1 Slag 4 T	1	0.12	0.05	4.77	27.30	1.68	0.11	0.35	0.55	0.49	0.07	0.11	1.43	66.14	635	141	13	553	83	1274	1109	1929	1522	886	103.98
	2	0.41	0.06	4.80	27.38	1.65	0.11	0.35	0.55	0.48	0.07	0.11	1.43	66.18	664	145	17	558	91	1241	1083	1866	1436	1159	104.41
	3	0.27	/	4.88	27.62	1.67	0.11	0.36	0.55	0.49	0.07	0.11	1.44	66.92	812	153	15	556	81	1271	1110	1878	1500	1166	105.35
Furnace Slag 1 M	1	0.39	0.39	10.86	31.16	1.63	0.17	2.47	1.98	/	/	0.09	7.34	49.70	/	152	61	1258	49	795	20923	301	2292	1441	108.89
	2	0.15	0.35	10.96	31.17	1.61	0.16	2.47	1.98	/	/	0.09	7.33	49.58	/	166	64	1257	47	783	20756	261	2282	1119	108.52
	3	0.13	0.43	10.98	31.13	1.62	0.16	2.49	1.99	/	/	0.10	7.37	49.76	/	141	63	1254	49	790	20990	301	2292	1139	108.86
Furnace Slag 2 M	1	0.31	0.36	8.39	28.45	1.89	0.14	1.76	1.40	0.28	0.01	0.09	3.51	61.13	473	210	78	374	34	395	7109	151	545	434	108.69
	2	0.18	0.40	8.23	27.97	1.86	0.14	1.72	1.37	0.27	0.01	0.08	3.44	59.91	241	213	75	367	33	409	7032	114	577	288	106.51
	3	0.27	0.32	8.38	28.34	1.89	0.14	1.77	1.40	0.27	0.01	0.08	3.49	60.94	350	206	79	376	35	382	7127	117	531	278	108.24
Furnace Slag 3 M	1	0.32	0.41	8.25	28.75	1.98	0.14	1.87	1.50	0.22	/	0.08	3.88	61.04	359	201	95	403	35	410	8274	62	468	481	109.51
	2	0.24	0.41	8.24	28.53	1.94	0.14	1.86	1.50	0.21	/	0.07	3.85	60.71	189	172	85	399	27	405	8255	91	473	512	108.76
	3	0.39	0.35	8.06	28.68	1.99	0.14	1.85	1.49	0.21	/	0.08	3.86	60.82	275	196	88	405	33	394	8252	62	453	349	108.97

Appendix L

PCA report: Rugombe (95.88% of variance explained in total)

Table L.1 Principal component scores

	PC1	PC2	PC3	PC4
C1 S1 M	0.40	-0.91	1.47	-0.33
C1 S2 M	1.02	1.16	-0.13	-1.61
C1 S3 T	0.96	0.36	-1.25	1.26
C1 S4 T	0.74	-0.67	0.59	0.88
FS1 M	-1.30	1.49	0.84	0.72
FS2 M	-0.84	-0.82	-0.71	-0.36
FS3 M	-0.97	-0.61	-0.83	-0.56

Table L.2 Loading vector values

Original	Loading Vectors			
Variables	1	2	3	4
MgO	-.96	-.14	.12	-.16
Al2O3	-.92	.15	.30	-.01
SiO2	-.68	-.28	.63	-.08
P2O5	.63	.34	-.07	-.67
K2O	-.98	.00	.17	.02
CaO	-.65	.11	.50	-.35
TiO2	.62	-.65	.40	-.19
V2O5	.92	-.14	.10	.34
Cr2O3	.14	-.39	.37	.82
MnO	-.81	.47	-.06	.34
FeO	.87	-.01	-.49	.08
Co3O4	.89	-.31	.19	-.25
CuO	.52	.27	-.62	.34
ZnO	-.85	.02	-.48	-.19
SrO	.39	.84	.23	-.28
Y2O3	.93	.18	.22	.00
ZrO2	.67	-.10	.69	.15
BaO	-.81	.52	.05	.26
La2O3	.91	.25	.13	-.16
CeO2	.26	.84	.40	.18
Nd2O3	.45	.77	.30	.19

Table L.3 Total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.67	55.55	55.55	11.67	55.55	55.55
2	3.61	17.19	72.75	3.61	17.19	72.75
3	2.83	13.46	86.20	2.83	13.46	86.20
4	2.03	9.68	95.88	2.03	9.68	95.88
5	.84	4.00	99.89			
6	.02	.11	100.00			
7	.00	.00	100.00			
8	.00	.00	100.00			
9	.00	.00	100.00			
10	.00	.00	100.00			
11	.00	.00	100.00			
12	.00	.00	100.00			
13	.00	.00	100.00			
14	.00	.00	100.00			
15	.00	.00	100.00			
16	.00	.00	100.00			
17	.00	.00	100.00			
18	.00	.00	100.00			
19	.00	.00	100.00			
20	.00	.00	100.00			
21	.00	.00	100.00			

Appendix M

PCA report: All early sites (83.62% of variance explained in total)

Table M.1 Principal component scores

	PC1	PC2	PC3	PC4	PC5	PC6
RGB C1 S1 M	-0.80	0.75	0.99	-0.21	1.21	1.01
RGB C1 S2 M	-1.27	2.44	1.68	-0.49	-1.47	-0.15
RGB C1 S3 T	-1.58	1.64	-0.71	0.24	-0.95	-1.37
RGB C1 S4 T	-1.08	1.02	0.02	-1.20	1.23	0.35
RGB FS1 M	1.51	0.43	0.31	-1.19	-2.56	-0.76
RGB FS2 M	0.29	-0.82	-0.10	-0.91	-1.78	-0.75
RGB FS3 M	0.43	-0.82	0.00	-0.96	-2.12	-0.90
MNG Tr3 S1 M	0.73	0.03	-1.13	0.77	-0.06	-0.95
MNG C1 S1 M	-0.32	-0.30	0.13	-0.26	0.46	-0.11
MNG C1 S3 M	-1.46	-0.53	-1.93	1.04	1.12	-1.92
MNG C1 S5 M	-0.99	0.39	-2.45	2.75	-2.08	3.47
MNG C1 S6 B	-0.28	0.07	0.40	-0.36	1.12	0.99
MNG C2 S1 M	1.78	0.98	1.17	2.13	0.60	-0.97
MNG C3 S1 B	1.33	-0.08	-1.70	-0.50	0.06	0.12
MNG C3 S2 M	2.04	0.54	1.44	3.09	0.00	-0.74
MNG C3 S4 B	2.29	1.99	-1.16	-1.78	0.73	1.23
MNG C3 S5 M	1.83	0.63	-2.25	-0.84	1.20	-0.21
MNG FS1 B	-0.67	1.18	0.34	-0.06	0.78	-0.17
MNG FS1 M	-1.05	0.68	-0.59	0.00	0.28	-1.00
MNG FS1 T	-0.91	0.90	-0.16	-0.12	0.47	-0.63
MNG FS2 M	-0.33	0.99	0.99	0.19	0.68	0.58
KTR Furnace slag M	0.04	-0.27	0.96	0.11	-0.16	0.33
KTR Furnace slag B	-0.42	-0.61	0.01	-0.05	-0.58	-0.73
KTR Slag 1 M	-0.56	-0.60	0.17	-0.79	-0.24	0.98
KTR Slag 2 M	0.03	-1.46	0.21	-0.03	0.57	0.62
KTR Slag 6 T	-0.20	-0.52	0.32	0.49	0.25	-0.42
KTR Slag 6 B	0.26	-0.91	0.85	0.04	-0.08	0.68
KTR Slag 7 B	0.17	-0.72	0.78	-0.42	-0.21	0.45
KTR Slag 8 M	-0.08	-0.54	0.42	-0.37	-0.10	0.61
KTR Slag 9 M	-0.28	-0.49	0.51	-0.37	-0.63	0.64
KTR Slag 10 T	-0.03	-1.04	0.44	-0.05	0.45	0.59
KTR Slag 10 M	-0.60	-1.05	-0.40	0.17	-0.13	-0.99
KTR Slag 10 B	-0.07	-1.39	0.10	-0.09	0.18	0.15
KTR Slag 11 M	-0.31	-1.35	-0.54	0.07	0.89	-0.91
KTR Slag 16 M	0.56	-1.17	0.86	0.00	0.86	0.88

Table M.2 Loading vector values

Original	Loading Vectors					
Variables	1	2	3	4	5	6
MgO	.71	.08	.27	.52	.12	-.22
Al2O3	.72	-.38	-.13	-.17	-.04	.18
SiO2	.62	-.51	.37	-.01	.20	.24
P2O5	-.49	.54	.48	.12	-.17	-.09
K2O	.69	-.38	.20	.21	-.05	.03
CaO	.54	-.26	.48	.43	.18	.06
TiO2	-.71	-.38	.28	-.10	.26	.39
V2O5	-.74	.03	.00	.16	.43	-.23
Cr2O3	-.17	-.31	-.57	.15	.33	-.28
MnO	.79	.43	-.33	.14	.02	-.12
FeO	-.94	.17	-.15	-.09	-.14	-.13
Co3O4	-.78	-.35	.01	.09	.03	.24
NiO	-.02	.11	-.50	.51	-.32	.57
CuO	-.53	.09	-.38	.53	-.32	-.02
ZnO	-.05	-.60	.31	-.31	-.47	-.04
SrO	.04	.58	.57	.22	-.32	-.16
Y2O3	.03	.74	.13	-.05	.30	.31
ZrO2	-.52	.60	.13	.04	.13	.15
BaO	.77	.39	-.38	-.25	-.04	-.01
La2O3	-.03	.90	.12	.02	.21	.10
CeO2	.12	.82	.15	-.24	-.20	.04
Nd2O3	.54	.69	-.24	-.19	.09	.12

Table M.3 Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.06	32.10	32.10	7.06	32.10	32.10
2	5.23	23.77	55.87	5.23	23.77	55.87
3	2.36	10.74	66.61	2.36	10.74	66.61
4	1.49	6.75	73.37	1.49	6.75	73.37
5	1.23	5.60	78.97	1.23	5.60	78.97
6	1.02	4.65	83.62	1.02	4.65	83.62
7	.96	4.35	87.97			
8	.64	2.91	90.88			
9	.53	2.43	93.31			
10	.46	2.08	95.39			
11	.27	1.21	96.59			
12	.22	1.01	97.61			
13	.15	.69	98.30			
14	.12	.56	98.86			
15	.09	.41	99.27			
16	.05	.24	99.51			
17	.04	.20	99.71			
18	.03	.14	99.85			
19	.02	.08	99.93			
20	.01	.06	99.99			
21	.00	.01	100.00			
22	.00	.00	100.00			

Appendix N

Unnormalised PED-XRF data: Kirongo

Table N.1 Ceramics

21/1/10		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	Co_3O_4 ppm	CuO ppm	ZnO ppm	SrO ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Pot A	1	0.32	0.25	24.98	55.53	0.01	0.04	0.39	0.26	1.26	0.02	0.02	0.01	3.62	65	73	64	61	449	405	122	191	134	86.86
	2	/	0.15	25.13	55.97	0.01	0.05	0.40	0.27	1.27	0.02	0.02	0.01	3.62	66	78	65	61	445	413	121	213	153	87.08
	3	0.25	0.26	25.18	56.14	0.01	0.05	0.40	0.27	1.27	0.02	0.02	0.01	3.63	57	79	64	61	449	400	101	174	118	87.67
Pot B	1	0.29	0.37	21.74	64.03	0.07	0.04	0.54	0.37	1.53	0.01	0.02	0.03	3.59	44	51	68	74	842	369	235	312	159	92.85
	2	/	0.22	21.83	64.46	0.07	0.04	0.55	0.37	1.53	0.02	0.02	0.03	3.60	57	54	68	74	865	365	245	343	200	92.96
	3	/	0.27	21.95	64.82	0.07	0.04	0.55	0.37	1.55	0.02	0.02	0.03	3.62	70	53	70	74	874	373	229	331	172	93.53
Furnace Wall	1	0.26	0.21	23.78	51.34	0.10	0.05	0.63	0.08	1.19	0.01	0.02	0.12	9.96	202	61	81	23	803	472	144	321	81	87.97
	2	0.23	0.19	23.80	51.34	0.10	0.05	0.63	0.08	1.19	0.01	0.02	0.12	9.96	225	60	81	22	839	471	149	314	79	87.93
	3	0.34	0.20	23.98	51.28	0.09	0.06	0.63	0.08	1.20	0.01	0.02	0.12	10.01	185	65	79	23	810	485	180	340	/	88.23

Table N.2 Ore

8/12/09	Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	NiO ppm	ZnO ppm	ZrO_2 ppm	BaO ppm	Analytical total (wt%)
Ore (from furnace)	/	0.74	2.39	2.96	/	0.03	0.03	0.01	5.37	/	0.06	11.16	73.73	334	586	64	536	96.64
	/	0.50	2.54	2.97	/	0.03	0.03	0.01	5.49	/	0.06	11.30	74.44	350	612	/	533	97.51
	/	0.42	2.53	2.94	/	0.03	0.03	0.00	5.55	/	0.06	11.32	74.24	328	585	84	535	97.27

Table N.3 KYS120 slag

7/12/09		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	Co_3O_4 ppm	CuO ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
KYS120 Slag A	1	0.44	0.35	8.28	34.14	1.11	0.07	1.71	2.77	0.42	/	0.08	7.94	51.10	/	96	287	83	632	14593	270	592	967	110.15
	2	0.25	0.43	8.30	34.21	1.09	0.06	1.71	2.76	0.40	/	0.08	7.88	50.73	/	100	284	82	606	14604	237	577	924	109.65
	3	0.38	0.48	8.15	33.42	1.08	0.07	1.67	2.71	0.41	/	0.08	7.70	49.81	/	97	282	79	626	14302	214	599	735	107.64
KYS120 Slag B	1	0.48	0.30	8.02	33.51	0.73	0.07	1.50	3.05	/	/	0.13	8.71	50.34	/	146	281	87	580	16781	609	1004	1067	108.89
	2	0.31	0.24	7.97	33.22	0.89	0.07	1.48	3.00	/	/	0.12	8.58	50.22	/	138	285	89	558	16826	587	1072	1057	108.16
	3	0.26	0.18	8.06	33.65	0.91	0.07	1.51	3.04	/	/	0.12	8.47	50.43	/	153	283	87	571	16870	648	1047	1020	108.78

Table N.4 KRG Slag

7/12/09		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	CuO ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Cluster 1 Slag 1 M	1	0.19	0.29	6.58	30.02	0.97	0.06	1.09	2.28	0.18	0.03	0.11	6.89	59.43	235	298	58	644	3904	340	500	201	108.75
	2	0.46	0.30	6.55	30.32	0.98	0.06	1.10	2.33	0.20	0.03	0.11	6.98	60.23	275	307	59	644	3926	369	494	302	110.29
	3	0.27	0.32	6.59	30.60	0.98	0.06	1.10	2.29	0.19	0.03	0.12	6.94	60.15	223	307	62	649	3939	335	515	400	110.29
Cluster 1 Slag 2 M	1	0.44	0.17	7.93	23.55	1.85	0.13	1.22	1.57	/	/	0.16	9.27	64.18	274	247	90	748	16736	513	1047	1067	112.55
	2	0.34	0.15	7.99	23.65	1.84	0.12	1.22	1.58	/	/	0.16	9.29	64.35	280	253	95	732	16803	475	1001	1069	112.75
	3	0.39	0.12	7.87	23.37	1.85	0.12	1.21	1.57	/	/	0.17	9.28	63.42	268	244	93	704	16558	546	1052	1072	111.42
Cluster 1 Slag 4 M	1	0.39	0.33	9.13	27.96	1.53	0.11	1.16	3.17	/	/	0.12	10.18	52.40	203	371	89	745	21593	325	2406	1201	109.16
	2	0.21	0.30	9.19	28.05	1.54	0.11	1.17	3.14	/	/	0.12	10.37	52.23	185	367	85	702	21448	397	2538	1174	109.11
	3	0.38	0.32	9.20	27.96	1.52	0.11	1.15	3.17	/	/	0.12	10.35	52.51	180	369	86	802	21615	332	2565	1145	109.50
Cluster 1 Slag 5 M	1	0.21	0.36	8.33	31.43	1.39	0.15	1.86	3.49	/	/	0.09	8.06	51.35	160	454	110	1121	23000	355	1368	1180	109.50
	2	0.26	0.25	8.09	31.05	1.38	0.15	1.84	3.48	/	/	0.09	8.02	50.93	158	450	110	1079	22777	386	1336	1372	108.31
	3	0.41	0.32	8.14	31.60	1.38	0.15	1.84	3.51	/	/	0.09	8.08	51.30	147	458	111	1065	23000	359	1333	1444	109.60
Cluster 1 Slag 6 M	1	0.36	0.17	9.89	28.91	2.13	0.08	1.31	2.35	/	/	0.08	9.85	52.66	107	385	136	734	10888	387	1286	623	109.25
	2	0.36	0.14	9.88	28.84	2.16	0.08	1.32	2.33	0.12	/	0.09	10.01	52.75	97	389	136	730	10790	326	1251	784	109.52
	3	0.68	0.06	10.09	29.56	2.17	0.08	1.32	2.41	/	/	0.08	10.04	53.69	96	400	140	767	11052	346	1241	664	111.65
Cluster 1 Slag 7 M	1	0.16	0.15	10.39	25.01	2.34	0.11	1.02	1.71	/	/	0.09	9.51	55.32	192	770	131	946	11522	225	676	596	107.31
	2	0.25	0.14	10.53	25.67	2.39	0.11	1.06	1.76	/	/	0.10	9.76	56.83	199	783	136	1013	11779	270	667	813	110.15
	3	0.28	0.07	10.33	25.02	2.33	0.11	1.03	1.71	/	/	0.09	9.59	55.38	184	760	128	965	11344	277	676	735	107.43
Cluster 1 Slag 9 M	1	0.36	0.16	7.17	27.16	1.25	0.10	1.29	1.50	0.18	0.01	0.16	7.24	61.30	181	206	76	539	12471	332	1065	903	109.44
	2	0.40	0.16	7.24	26.71	1.23	0.10	1.27	1.47	0.18	0.01	0.16	7.18	60.47	197	204	76	510	12226	329	1106	712	108.11
	3	0.31	0.23	7.23	27.27	1.26	0.10	1.29	1.49	0.18	0.01	0.16	7.26	61.39	195	210	78	525	12482	248	1079	887	109.74
Cluster 2 Slag 1 M	1	0.23	0.27	8.86	24.15	1.23	0.08	1.33	2.33	/	/	0.14	13.07	58.99	391	476	82	530	22687	107	1036	1022	113.32
	2	0.19	0.23	8.94	23.97	1.25	0.08	1.31	2.32	/	/	0.14	12.97	58.72	424	467	80	473	22598	111	1054	1074	112.75
	3	0.34	0.24	8.86	24.11	1.23	0.08	1.32	2.37	/	/	0.14	13.02	58.45	420	470	77	504	22486	84	1059	1132	112.78
Cluster 2 Slag 2 T	1	0.29	0.60	10.81	32.89	1.36	0.11	2.13	3.33	/	/	0.10	8.95	46.78	225	279	81	745	14101	109	466	761	109.03
	2	0.21	0.69	10.85	33.00	1.33	0.11	2.21	3.37	/	/	0.10	9.18	47.39	258	286	81	783	14146	70	405	719	110.11
	3	0.33	0.61	10.73	32.80	1.37	0.11	2.16	3.36	/	/	0.10	8.88	47.00	244	281	83	701	14101	122	404	741	109.11
Cluster 2 Slag 3 M	1	0.37	0.56	12.35	29.98	1.09	0.09	1.39	3.37	/	/	0.16	10.37	46.85	174	327	104	625	20108	162	1606	1225	109.02
	2	0.46	0.47	12.52	30.47	1.10	0.09	1.37	3.39	/	/	0.16	10.31	47.04	181	324	104	625	20153	151	1561	1009	109.80
	3	0.16	0.51	12.37	29.89	1.08	0.09	1.39	3.36	/	/	0.16	10.23	46.48	164	327	102	614	19985	200	1596	1190	108.15
Furnace Slag C	1	0.26	0.28	8.35	33.14	1.28	0.09	2.07	3.89	0.35	/	0.04	7.97	51.10	269	542	126	732	12572	620	1336	913	110.54
	2	0.27	0.32	8.69	34.26	1.35	0.10	2.13	4.00	0.34	/	0.04	8.15	52.64	294	557	130	814	12884	519	1355	858	114.02
	3	0.34	0.24	8.26	33.01	1.28	0.09	2.08	3.83	0.36	/	0.04	7.91	50.81	265	531	125	770	12516	530	1306	869	109.95
Furnace Slag T	1	0.48	0.36	8.80	28.62	1.15	0.09	1.57	3.45	0.33	/	0.13	8.02	55.67	294	462	104	650	10050	430	1120	703	110.06
	2	0.20	0.44	8.75	28.55	1.15	0.09	1.60	3.44	0.32	/	0.13	7.99	55.33	276	460	102	621	9957	441	1092	801	109.35
	3	0.35	0.32	8.64	28.67	1.16	0.09	1.59	3.46	0.31	/	0.13	7.96	55.50	288	464	107	635	10024	429	1150	559	109.55
Furnace Slag M	1	0.55	0.39	7.59	30.97	1.24	0.09	1.83	3.72	0.31	/	0.06	8.27	55.37	284	490	111	679	10939	500	1290	713	111.90
	2	0.21	0.31	7.60	30.97	1.27	0.09	1.82	3.70	0.32	/	0.06	8.18	55.10	300	491	110	667	10802	476	1204	829	111.12
	3	0.35	0.29	7.54	30.94	1.25	0.09	1.81	3.69	0.32	/	0.06	8.24	54.99	285	491	113	687	10842	462	1188	717	111.06
Furnace Slag B	1	0.40	0.47	7.81	29.50	1.02	0.09	1.63	3.61	0.29	/	0.07	8.23	56.47	207	427	104	610	9115	411	950	670	110.84
	2	0.31	0.50	7.90	30.08	1.02	0.09	1.66	3.65	0.32	/	0.08	8.33	57.36	199	428	103	614	9249	424	951	641	112.54
	3	0.38	0.41	7.78	29.48	0.98	0.09	1.58	3.55	0.31	/	0.07	8.12	55.88	212	421	99	655	9070	396	975	585	109.88

Appendix O

PCA report: Kirongo (83.09% of variance explained in total)

Table O.1 Principal component scores

	PC1	PC2	PC3	PC4	PC5
C1S1M	-2.49	0.09	-0.20	-0.69	-0.71
C1S2M	-0.53	-1.65	0.00	0.99	-0.01
C1S4M	1.05	-0.74	-0.59	1.19	-0.05
C1S5M	1.26	0.37	0.30	1.11	-0.80
C1S6M	0.42	-0.46	1.41	-0.31	-1.10
C1S7M	0.55	-1.33	2.27	-1.41	-0.43
C1S9M	-1.46	-0.83	-0.61	0.53	-0.78
C2S1M	0.23	-1.57	-1.14	-0.78	2.28
C2S2T	0.65	1.06	-1.01	-2.12	-0.40
C2S3M	1.43	-0.15	-1.47	-0.67	-0.56
FS Bl	0.31	1.42	1.11	0.72	1.08
FS T	-0.41	0.43	0.18	-0.01	1.11
FS M	-0.25	0.92	0.70	0.41	1.34
FS B	-0.55	0.90	0.24	-0.11	0.72
KYS120 A	-0.26	1.15	-0.47	-0.32	-0.97
KYS120 B	0.06	0.39	-0.72	1.47	-0.72

Table O.2 Loading vector values

Original	Loading Vectors				
Variables	1	2	3	4	5
MgO	.21	.63	-.53	-.38	.04
Al2O3	.74	-.11	-.08	-.51	-.18
SiO2	.11	.89	-.12	.04	-.33
P2O5	.30	-.53	.67	-.19	-.21
K2O	.28	.82	-.06	-.03	.16
CaO	.42	.79	-.09	.13	.29
TiO2	-.45	.63	.24	.06	.24
V2O5	-.78	-.07	-.12	-.11	-.26
Cr2O3	-.10	-.66	-.59	.05	-.16
MnO	.58	-.58	-.20	-.24	.31
FeO	-.72	-.58	.19	.16	.16
CuO	-.19	-.20	-.14	-.15	.86
SrO	.33	-.06	.73	-.21	.37
Y2O3	.52	.06	.77	.03	.03
ZrO2	.47	.01	.58	.02	-.31
BaO	.73	-.30	-.44	.29	.04
La2O3	-.22	.23	.36	.77	.05
CeO2	.50	-.18	-.10	.58	.11
Nd2O3	.71	-.23	-.34	.49	-.03

Table O.3 Total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.58	24.13	24.13	4.58	24.13	24.13
2	4.56	24.00	48.13	4.56	24.00	48.13
3	3.20	16.82	64.95	3.20	16.82	64.95
4	1.89	9.93	74.87	1.89	9.93	74.87
5	1.56	8.21	83.09	1.56	8.21	83.09
6	.90	4.76	87.85			
7	.72	3.77	91.61			
8	.48	2.54	94.16			
9	.44	2.30	96.45			
10	.31	1.63	98.08			
11	.20	1.05	99.13			
12	.09	.48	99.61			
13	.05	.24	99.86			
14	.02	.13	99.99			
15	.00	.01	100.00			
16	.00	.00	100.00			
17	.00	.00	100.00			
18	.00	.00	100.00			
19	.00	.00	100.00			

Appendix P

Macroscopic tuyère descriptions: Kisamura

Context	Colour	Inclusions	Thickness (cm)	Internal diam. (cm)	Notes
40	Orangey grey	Frequent coarse quartz	1.6	/	Vitrified
40	Orangey grey, white	Grog, quartz	1.11	/	Vitrified
40	Orangey grey, white	Grog, quartz	2.41	/	Vitrified
40	Brownish grey	Quartz	1.21	5	Vitrified
40	Brownish grey	Quartz	1.33	6	Vitrified
40	Greyish brown, white	Coarse quartz, grog	2.05	3	Vitrified
40	Greyish brown, white	Coarse quartz, grog	1.88	4	Vitrified
40	Greyish brown, white	Coarse quartz, grog	1.75	/	Vitrified
40	Greyish white	Quartz, grog	2.06	6	Vitrified
		Averages:	**1.7**	**4.8**	

Appendix Q

Unnormalised PED-XRF data: Kisamura

Table Q.1 Ceramics

25/1/10		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	NiO	CuO	ZnO	Rb_2O	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Tuyère	1	/	0.10	23.61	71.62	/	0.03	1.89	0.13	1.03	0.00	0.01	0.03	2.42	44	30	76	49	81	34	15	516	352	86	118	169	101.01
	2	0.40	0.24	23.76	72.00	/	0.03	1.89	0.13	1.05	0.01	0.01	0.03	2.43	39	29	69	49	82	34	14	500	345	49	67	90	102.09
	3	0.29	0.23	23.75	72.10	/	0.03	1.90	0.13	1.04	0.01	0.01	0.03	2.43	47	29	73	50	80	33	15	505	340	46	70	76	102.07
Pot	1	0.36	0.47	22.31	62.79	0.05	0.04	1.04	0.48	1.24	0.02	0.03	0.03	4.95	82	63	77	84	62	58	30	547	321	105	130	132	93.96
	2	0.35	0.43	22.34	62.79	0.05	0.05	1.05	0.48	1.24	0.02	0.03	0.03	4.95	81	62	77	85	63	58	30	527	317	129	146	68	93.96
	3	0.35	0.45	22.25	62.68	0.07	0.04	1.04	0.48	1.24	0.02	0.03	0.03	4.94	76	63	80	84	62	58	29	555	321	108	114	85	93.77
Furnace Wall	1	0.24	0.64	23.32	40.03	0.87	0.09	1.05	0.89	1.62	0.04	0.03	0.32	17.46	376	64	216	145	58	73	78	448	432	165	208	125	86.81
	2	0.17	0.65	23.43	40.35	0.87	0.09	1.07	0.89	1.63	0.04	0.03	0.32	17.55	327	65	216	146	56	76	80	473	454	190	226	198	87.32
	3	0.17	0.62	23.32	40.10	0.86	0.10	1.07	0.89	1.62	0.04	0.03	0.32	17.57	322	66	212	145	55	75	79	462	450	190	213	102	86.93

Table Q.2 Ore

14/1/10		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	NiO	CuO	ZnO	SrO	Y_2O_3	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Ore A	1	0.05	0.03	6.86	35.74	0.64	0.07	0.28	0.04	0.13	0.06	0.54	0.26	58.99	594	/	381	80	224	17	154	216	271	225	/	103.90
	2	0.21	/	6.78	35.51	0.63	0.06	0.28	0.04	0.13	0.06	0.54	0.25	58.76	441	/	386	79	223	16	146	204	307	285	123	103.47
	3	0.29	/	6.83	35.73	0.63	0.06	0.28	0.05	0.13	0.06	0.53	0.26	58.99	706	/	360	86	222	17	139	220	280	270	/	104.07
Ore B	1	0.24	/	22.76	18.17	0.46	0.08	0.45	1.37	/	/	0.09	19.52	16.54	/	1159	1617	618	115	169	185	37269	727	1254	3144	84.30
	2	/	/	22.97	18.10	0.48	0.08	0.45	1.37	/	/	0.08	19.59	16.71	/	1171	1630	631	116	165	175	37548	737	1302	2982	84.48
	3	0.21	/	22.57	18.40	0.46	0.08	0.48	1.36	/	/	0.08	19.54	16.67	/	1139	1587	630	116	166	183	37146	723	1204	2941	84.44
Ore C	1	0.30	/	1.27	80.81	/	0.03	/	0.02	0.03	0.01	0.01	0.08	29.61	478	34	162	29	/	5	67	/	/	47	/	112.26
	2	0.53	/	1.26	80.70	/	0.03	/	0.03	0.04	0.01	0.01	0.08	29.67	428	29	164	28	/	5	67	/	/	/	46	112.43
	3	0.29	/	1.29	80.57	/	0.03	0.01	0.03	0.03	0.01	0.01	0.08	29.74	450	41	184	31	/	7	62	/	39	/	46	112.18

Table Q.3 Slag

24/11/09		Na_2O wt%	MgO wt%	Al_2O_3 wt%	SiO_2 wt%	P_2O_5 wt%	S wt%	K_2O wt%	CaO wt%	TiO_2 wt%	V_2O_5 wt%	Cr_2O_3 wt%	MnO wt%	FeO wt%	CuO ppm	ZnO ppm	SeO_2 ppm	SrO ppm	Y_2O_3 ppm	ZrO_2 ppm	BaO ppm	La_2O_3 ppm	CeO_2 ppm	Nd_2O_3 ppm	Analytical total (wt%)
Cluster 1 Slag 1 M	1	0.49	0.30	7.17	28.49	1.68	0.12	2.57	1.67	/	0.01	0.12	9.13	60.93	482	25	57	465	91	777	7290	1048	909	827	113.86
	2	/	0.32	7.10	28.75	1.70	0.12	2.59	1.67	/	0.02	0.11	9.26	61.01	476	22	64	469	92	799	7392	1099	967	617	113.85
	3	0.17	0.34	7.18	28.60	1.69	0.12	2.56	1.67	/	0.01	0.11	9.14	60.78	474	24	51	467	88	731	7322	1129	1036	1023	113.61
Cluster 1 Slag 2 T	1	0.16	0.48	7.09	25.33	2.08	0.13	2.31	1.61	0.15	0.05	0.14	6.85	66.57	398	18	68	476	90	851	4009	961	1013	635	113.79
	2	0.24	0.50	6.97	25.18	2.06	0.13	2.33	1.59	0.14	0.05	0.14	6.78	65.84	393	19	44	460	93	834	4021	1001	1074	442	112.79
	3	0.24	0.43	6.99	25.39	2.03	0.12	2.29	1.60	0.15	0.05	0.14	6.82	66.15	368	11	45	469	92	848	4018	1026	1056	721	113.28
Cluster 1 Slag 3 M	1	0.12	0.45	5.80	28.42	1.72	0.09	1.92	2.15	0.11	0.03	0.10	7.84	60.38	171	15	34	485	105	978	3661	1471	951	728	109.97
	2	0.37	0.41	5.81	28.41	1.71	0.08	1.92	2.13	0.10	0.02	0.10	7.77	59.98	174	18	51	478	102	1038	3583	1385	911	682	109.67
	3	0.48	0.39	5.94	28.69	1.75	0.09	1.95	2.15	0.11	0.03	0.10	7.96	60.77	176	18	38	485	112	1069	3674	1449	920	680	111.26
Cluster 1 Slag 4 M	1	0.28	0.31	6.62	26.44	1.90	0.18	2.12	1.67	0.19	0.05	0.12	6.25	62.83	312	15	92	390	75	989	5660	959	1038	644	109.98
	2	0.21	0.36	6.62	26.31	1.90	0.19	2.10	1.67	0.19	0.05	0.13	6.27	62.43	275	18	95	384	72	936	5664	989	1024	727	109.44
	3	0.09	0.39	6.58	26.16	1.86	0.18	2.10	1.68	0.19	0.05	0.12	6.22	62.22	304	19	91	389	71	883	5633	968	1045	644	108.85
Cluster 1 Slag 5 M	1	0.18	0.32	7.68	27.63	1.85	0.25	3.07	1.28	0.19	0.06	0.12	5.53	58.86	193	13	113	245	56	730	5350	741	837	605	107.91
	2	0.24	0.33	7.90	27.60	1.84	0.25	3.05	1.28	0.19	0.06	0.12	5.53	58.84	188	11	92	245	60	703	5328	749	829	589	108.12
	3	0.37	0.32	7.68	27.19	1.83	0.25	3.01	1.27	0.18	0.07	0.12	5.50	58.09	219	17	124	251	56	684	5278	723	851	568	106.75
Cluster 1 Slag 6 B	1	0.16	0.34	6.83	22.75	1.55	0.13	2.13	1.26	0.14	0.02	0.09	9.29	61.49	339	7	/	289	86	542	3461	438	751	286	106.80
	2	0.28	0.45	6.62	22.35	1.50	0.12	2.11	1.24	0.15	0.01	0.09	9.24	61.07	409	8	24	289	84	519	3409	416	721	352	105.84
	3	0.31	0.40	6.86	22.94	1.55	0.13	2.17	1.29	0.14	0.02	0.09	9.51	63.08	400	12	25	302	93	545	3537	470	735	376	109.13
Cluster 1 Slag 6 C	1	0.12	0.23	8.44	25.35	2.21	0.17	2.68	1.69	0.08	0.01	0.09	8.11	54.65	275	26	77	490	139	786	5868	1020	1532	760	104.92
	2	0.26	0.41	8.39	25.38	2.20	0.17	2.68	1.72	0.07	/	0.09	8.13	54.95	292	26	77	499	133	817	5881	1020	1536	790	105.56
	3	/	0.33	8.52	25.02	2.16	0.16	2.66	1.68	0.10	0.01	0.09	8.29	54.47	271	17	40	492	135	819	5863	994	1528	805	104.58
Cluster 1 Slag 6 M	1	0.33	0.42	8.64	27.38	2.46	0.15	3.05	1.85	/	0.02	0.10	9.54	55.95	174	15	49	483	127	686	5414	854	1201	787	110.86
	2	0.12	0.49	8.82	27.61	2.50	0.15	3.13	1.88	/	0.02	0.10	9.67	56.40	174	20	79	493	122	708	5460	791	1157	656	111.85
	3	0.56	0.52	8.87	27.84	2.49	0.15	3.17	1.89	/	0.02	0.10	9.85	57.47	176	23	61	493	128	758	5615	875	1201	745	113.95
Cluster 1 Slag 6 T	1	0.47	0.42	7.80	27.30	2.37	0.16	2.89	1.79	/	0.02	0.13	8.97	59.15	219	13	54	475	127	741	5472	940	1440	734	112.50
	2	0.38	0.40	7.91	27.29	2.36	0.16	2.88	1.78	/	0.02	0.13	8.91	58.81	229	10	57	475	126	703	5493	918	1405	703	112.04
	3	0.19	0.40	7.81	27.24	2.32	0.16	2.83	1.78	/	0.01	0.13	8.87	58.40	221	12	59	477	125	764	5468	844	1416	719	111.16
Cluster 2 Slag 1 M	1	0.20	0.29	9.53	25.89	1.12	0.13	0.98	1.81	/	/	0.15	9.84	56.12	242	43	15	312	84	580	18545	466	1079	1370	108.31
	2	0.25	0.30	9.42	26.25	1.12	0.13	0.98	1.85	/	/	0.15	9.92	56.49	226	42	20	305	84	544	18567	499	1083	1386	109.13
	3	0.29	0.29	9.29	25.48	1.11	0.12	0.96	1.84	/	/	0.15	9.73	55.48	265	46	33	301	83	573	18322	490	1066	1369	107.00
Cluster 2 Slag 2 M	1	0.22	0.26	9.10	29.53	1.63	0.11	1.23	2.14	/	/	0.09	12.79	48.61	264	35	/	371	151	1066	25825	789	1437	2032	108.90
	2	0.39	0.30	9.04	29.43	1.60	0.11	1.22	2.17	/	/	0.09	13.60	48.81	290	41	/	376	159	1115	26182	741	1510	1990	110.01
	3	0.32	0.31	9.17	29.87	1.62	0.12	1.26	2.24	/	/	0.08	13.86	49.55	281	36	/	384	157	1101	26584	815	1483	2152	111.70
Cluster 2 Slag 3 M	1	0.40	0.21	8.25	31.83	1.26	0.13	0.53	1.80	/	/	0.08	12.73	52.65	187	45	23	446	141	839	5676	783	956	682	110.86
	2	0.31	0.14	8.17	31.42	1.24	0.14	0.52	1.76	/	/	0.08	12.51	51.89	176	41	26	449	138	837	5662	868	1036	745	109.17
	3	0.31	0.26	8.15	31.39	1.24	0.13	0.53	1.75	/	/	0.08	12.53	51.69	191	49	39	440	136	865	5648	765	954	666	109.04
Cluster 3 Slag 1 M	1	0.43	0.25	9.37	25.87	2.22	0.22	1.16	2.12	/	/	0.11	10.37	55.12	570	55	55	814	193	990	10008	1125	1619	1196	108.89
	2	0.46	0.26	9.55	26.26	2.20	0.23	1.19	2.12	/	/	0.11	10.45	55.33	586	53	48	823	191	1008	10085	1079	1633	998	109.82
	3	0.25	0.25	9.70	26.50	2.23	0.22	1.20	2.17	/	/	0.11	10.53	56.43	604	57	51	841	191	976	10232	1101	1631	1064	111.28
Cluster 3 Slag 2 M	1	0.32	0.53	6.24	29.79	1.64	0.11	2.29	1.98	0.12	0.03	0.11	6.55	57.47	232	18	59	402	93	924	4374	1138	936	696	108.07
	2	0.29	0.64	6.41	30.07	1.64	0.12	2.33	1.99	0.13	0.03	0.11	6.65	58.06	232	19	62	400	95	918	4376	1215	941	728	109.38
	3	0.23	0.55	6.37	30.30	1.66	0.12	2.33	2.02	0.14	0.03	0.11	6.72	58.49	238	29	85	408	95	898	4371	1268	1016	748	109.97
Furnace Slag 1 M	1	0.17	0.29	7.55	25.33	2.09	0.16	0.98	2.24	/	/	0.08	10.12	57.56	503	17	30	755	149	1199	15207	1176	1631	1333	108.77
	2	0.33	0.23	7.69	25.49	2.10	0.16	1.00	2.28	/	/	0.08	10.22	57.59	494	29	58	746	151	1197	15173	1171	1528	1403	109.37
	3	0.41	/	7.41	25.36	2.08	0.16	0.97	2.21	/	/	0.08	10.17	57.33	526	27	43	741	152	1176	15095	1294	1717	1460	108.40

Appendix R

PCA report: Kisamura (90.72% of variance explained in total)

Table R.1 Principal component scores

	PC1	PC2	PC3	PC4	PC5	PC6
C1 S1 M	-0.21	-0.12	0.14	-0.71	-0.36	0.43
C1 S2 T	-1.05	0.42	0.66	-0.78	0.55	-0.48
C1 S3 M	-0.38	0.71	-1.81	-0.71	-0.13	-0.66
C1 S4 M	-1.01	0.44	-0.17	-0.51	1.22	0.40
C1 S5 M	-1.46	-0.42	0.02	0.96	1.08	1.24
C1 S6 B	-0.93	-1.09	1.10	-1.58	-1.87	-0.90
C1 S6 Bl	0.14	0.82	0.61	1.13	-0.54	0.15
C1 S6 M	-0.17	0.15	0.31	1.91	-1.20	-0.50
C1 S6 T	-0.25	0.30	0.62	1.31	-0.57	-0.63
C2 S1 M	0.55	-2.14	1.01	-0.10	1.63	-0.09
C2 S2 M	1.80	-0.94	-0.78	0.58	0.67	-1.72
C2 S3 M	0.92	-1.25	-1.42	-0.31	-1.39	2.07
C3 S1 M	1.43	1.25	1.19	-0.20	0.25	1.53
C3 S2 M	-0.67	0.37	-1.75	0.25	0.39	-0.30
FS1 M	1.30	1.50	0.26	-1.23	0.27	-0.54

Table R.2 Loading vector values

Original	Loading Vectors					
Variables	1	2	3	4	5	6
MgO	-.66	.08	-.20	.25	-.09	-.40
Al2O3	.65	-.27	.46	.45	.11	.20
SiO2	.27	-.19	-.82	.30	.01	.30
P2O5	-.08	.77	.35	.46	-.15	-.11
K2O	-.73	.24	.15	.50	-.14	-.17
CaO	.75	.38	-.34	.02	.20	-.21
TiO2	-.80	.09	-.13	-.18	.22	.02
V2O5	-.87	.13	-.12	.06	.30	.06
Cr2O3	-.42	-.16	.36	.14	.62	.04
MnO	.87	-.34	-.01	-.03	-.32	-.06
FeO	-.80	.24	.26	-.44	.07	-.06
CuO	.32	.41	.52	-.54	.05	.10
ZnO	.79	-.20	.02	-.02	.20	.44
SeO2	-.61	.43	.00	.34	.28	.43
SrO	.57	.74	.18	-.13	-.09	.18
Y2O3	.85	.36	.07	.12	-.26	.04
ZrO2	.51	.61	-.45	-.17	.25	-.09
BaO	.74	-.30	.08	.02	.45	-.32
La2O3	.07	.82	-.47	-.10	.09	.03
CeO2	.72	.49	.29	.28	.11	-.09
Nd2O3	.81	-.12	-.02	.07	.44	-.31

Table R.3 Total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.15	43.57	43.57	9.15	43.57	43.57
2	3.58	17.06	60.63	3.58	17.06	60.63
3	2.24	10.66	71.29	2.24	10.66	71.29
4	1.63	7.78	79.07	1.63	7.78	79.07
5	1.42	6.76	85.83	1.42	6.76	85.83
6	1.03	4.89	90.72	1.03	4.89	90.72
7	.85	4.04	94.76			
8	.41	1.95	96.71			
9	.32	1.50	98.21			
10	.16	.78	99.00			
11	.11	.50	99.50			
12	.07	.34	99.85			
13	.02	.09	99.93			
14	.01	.07	100.00			
15	.00	.00	100.00			
16	.00	.00	100.00			
17	.00	.00	100.00			
18	.00	.00	100.00			
19	.00	.00	100.00			
20	.00	.00	100.00			
21	.00	.00	100.00			

Appendix S

Unnormalised PED-XRF data: Rukomero

Table S.1 Ceramics

21/1/10		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	NiO	CuO	ZnO	Rb_2O	SrO	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Furnace 1 Furnace Wall	1	0.18	0.27	22.93	50.15	0.36	0.08	1.32	0.06	1.03	0.02	0.02	0.07	9.27	124	41	91	46	96	22	627	466	156	583	168	86.01
	2	0.21	0.29	22.99	50.26	0.38	0.09	1.32	0.06	1.03	0.02	0.02	0.07	9.28	130	43	90	46	96	22	636	472	170	585	167	86.27
	3	0.22	0.26	23.10	50.62	0.38	0.09	1.33	0.06	1.04	0.02	0.02	0.07	9.28	217	36	88	47	97	22	666	480	192	608	117	86.76
Furnace 2 Furnace Wall	1	0.17	0.26	22.82	50.75	0.30	0.06	1.22	0.04	0.99	0.01	0.02	0.12	9.06	182	37	101	53	100	18	587	365	259	457	155	86.05
	2	0.29	0.31	22.90	51.17	0.30	0.07	1.23	0.04	0.99	0.01	0.02	0.12	9.10	158	41	93	52	100	19	585	358	222	450	204	86.77
	3	0.25	0.35	22.88	51.22	0.31	0.08	1.24	0.04	1.00	0.01	0.02	0.12	9.12	186	40	98	54	100	18	590	363	253	464	172	86.85
Furnace 2 Pot	1	0.25	0.56	26.32	53.05	0.05	0.07	1.17	0.12	1.20	0.01	0.01	0.03	3.77	72	32	39	59	62	63	687	847	383	484	338	86.92
	2	0.27	0.53	26.38	53.43	0.06	0.07	1.18	0.12	1.20	0.01	0.01	0.03	3.80	67	31	41	60	63	64	683	848	391	484	300	87.41
	3	0.37	0.56	26.43	53.15	0.05	0.07	1.18	0.12	1.21	0.01	0.01	0.03	3.80	53	35	42	61	63	63	701	851	332	444	273	87.27

Table S.2 Ore

8/12/09		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	La_2O_3	CeO_2	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	total (wt%)
Furnace 1 Ore	1	0.23	0.05	3.30	19.29	0.05	0.04	0.06	0.01	0.03	0.01	0.01	0.06	83.17	912	211	101	106.41
	2	0.13	/	3.34	19.07	0.04	0.04	0.06	0.01	0.03	0.01	0.01	0.06	82.38	804	185	55	105.27
	3	/	/	3.27	19.20	0.04	0.04	0.06	0.01	0.03	0.01	0.01	0.06	82.85	759	170	103	105.67
Fiurnace 2 Ore	1	/	0.04	1.59	15.64	/	0.02	0.04	0.01	0.01	/	0.02	0.04	89.20	859	/	55	106.70
	2	/	0.06	1.63	15.58	/	0.02	0.04	0.01	0.01	/	0.02	0.04	88.42	637	/	/	105.89
	3	/	/	1.66	15.31	/	0.02	0.04	0.01	0.01	/	0.02	0.04	88.10	969	/	/	105.31

Table S.3 Slag

8/12/09		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	Co_3O_4	CuO	SrO	ZrO_2	BaO	La_2O_3	CeO_2	Nd_2O_3	Analytical
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (wt%)
Furnace 1 Slag 1 M	1	0.27	0.11	4.25	27.31	0.04	0.08	0.27	0.50	0.17	0.02	0.01	2.52	62.78	421	44	76	91	3518	86	55	165	98.79
	2	0.10	/	4.42	27.96	0.04	0.09	0.28	0.51	0.18	0.02	0.01	2.58	64.10	518	79	74	85	3577	76	80	282	100.77
	3	0.13	0.08	4.34	27.80	0.04	0.08	0.28	0.51	0.18	0.02	0.01	2.56	63.59	448	110	78	115	3559	100	154	172	100.09
Furnace 1 Slag 2 M	1	0.27	0.14	4.84	28.72	0.06	0.05	0.55	0.96	0.15	0.00	0.02	3.19	67.20	354	48	152	111	4636	57	108	238	106.74
	2	0.12	0.12	4.93	28.85	0.04	0.05	0.56	0.97	0.16	/	0.02	3.21	67.83	259	60	154	74	4703	70	103	362	107.44
	3	0.40	0.16	4.89	28.95	0.06	0.05	0.56	0.96	0.16	0.00	0.02	3.20	67.33	416	93	156	73	4638	107	188	338	107.34
Furnace 1 Slag 3 M	1	0.34	0.13	4.63	29.43	0.06	0.06	0.45	0.85	0.19	0.01	0.02	2.89	66.40	362	72	105	103	3543	97	84	275	105.92
	2	0.13	0.15	4.57	29.33	0.08	0.06	0.45	0.84	0.19	0.01	0.02	2.88	66.10	432	55	106	95	3521	127	70	/	105.25
	3	0.10	0.14	4.65	29.11	0.07	0.06	0.45	0.84	0.19	0.01	0.02	2.89	66.49	417	44	108	71	3577	94	91	288	105.48
Furnace 2 Slag 1 M	1	0.14	0.28	6.06	40.25	0.08	0.07	1.03	1.96	0.21	0.01	0.02	3.46	57.11	267	19	182	113	1382	120	330	/	110.90
	2	0.11	0.21	6.03	40.13	0.07	0.07	1.02	1.96	0.21	0.01	0.02	3.44	57.09	226	34	182	114	1369	86	275	/	110.58
	3	0.37	0.30	6.07	40.03	0.08	0.07	1.00	1.93	0.20	0.00	0.02	3.41	56.82	185	/	179	94	1352	80	267	273	110.56
Furnace 2 Slag 2 T	1	0.24	0.22	6.83	38.32	/	0.04	0.67	1.28	0.25	0.00	0.02	3.51	56.93	/	50	111	150	946	118	251	/	108.49
	2	0.24	0.17	6.90	38.32	0.02	0.04	0.66	1.28	0.25	0.00	0.02	3.50	56.70	268	60	116	138	949	159	328	201	108.32
	3	0.30	0.17	6.86	38.37	0.02	0.04	0.66	1.28	0.25	/	0.02	3.51	56.93	226	13	111	148	949	128	278	/	108.59
Furnace 2 Slag 3 M	1	0.32	/	6.75	37.34	0.05	0.05	0.66	1.10	0.22	0.00	0.02	3.49	56.93	186	25	108	113	1410	134	318	76	107.17
	2	0.27	0.13	6.60	37.45	0.03	0.05	0.67	1.10	0.22	0.00	0.02	3.49	56.85	169	50	108	122	1417	182	311	/	107.12
	3	0.34	0.08	6.54	37.20	0.05	0.05	0.66	1.08	0.21	0.00	0.02	3.45	56.74	136	30	110	137	1409	145	344	88	106.68

Appendix T

PCA report: All later sites (79.73% of variance explained in total)

Table T.1 Principal component scores

	PC1	PC2	PC3	PC4
KSM C1 S1 M	0.51	1.11	-0.37	0.17
KSM C1 S2 T	0.35	1.85	0.45	-0.81
KSM C1 S3 M	0.33	1.26	0.43	0.78
KSM C1 S4 M	0.26	1.89	0.50	-0.39
KSM C1 S5 M	0.05	2.07	1.29	-1.17
KSM C1 S6 B	-0.07	0.94	-0.01	-0.82
KSM C1 S6 Bl	0.87	0.96	0.11	0.66
KSM C1 S6 M	0.70	0.95	0.74	-0.12
KSM C1 S6 T	0.65	0.98	0.40	-0.42
KSM C2 S1 M	0.56	-0.42	-1.30	-0.94
KSM C2 S2 M	1.24	-1.11	-1.20	0.54
KSM C2 S3 M	0.40	-0.15	-1.15	1.81
KSM C3 S1 M	1.54	0.54	-1.64	1.99
KSM C3 S2 M	0.36	1.44	1.17	0.44
KSM FS1 M	1.28	0.30	-1.73	1.50
RKM F1 S1 M	-2.31	0.45	-1.50	-0.20
RKM F1 S2 M	-2.02	0.17	-1.19	-0.21
RKM F1 S3 M	-2.19	0.36	-1.06	-0.17
RKM F2 S1 M	-1.86	-0.41	0.72	0.97
RKM F2 S2 T	-1.89	-0.42	0.34	0.91
RKM F2 S3 M	-1.92	-0.36	-0.07	0.82

	PC1	PC2	PC3	PC4
KRG Cluster 1 Slag 1 M	-0.57	0.29	0.50	-0.47
KRG Cluster 1 Slag 2 M	0.24	-0.17	-1.39	-1.95
KRG Cluster 1 Slag 4 M	0.72	-1.30	-0.19	-1.01
KRG Cluster 1 Slag 5 M	0.60	-1.23	0.34	-0.06
KRG Cluster 1 Slag 6 M	0.24	-0.82	-0.21	0.19
KRG Cluster 1 Slag 7 M	0.53	-0.50	-1.10	0.09
KRG Cluster 1 Slag 9 M	-0.25	-0.07	-0.44	-1.67
KRG Cluster 2 Slag 1 M	0.45	-0.86	-1.11	-1.76
KRG Cluster 2 Slag 2 T	0.28	-1.18	1.73	-0.59
KRG Cluster 2 Slag 3 M	0.76	-1.72	0.87	-1.55
KRG Furnace Slag Upper	0.20	-0.91	1.23	1.77
KRG Furnace Slag T	0.17	-0.60	0.92	0.00
KRG Furnace Slag M	0.07	-0.64	0.93	1.05
KRG Furnace Slag B	-0.09	-0.59	1.18	0.51
KYS120 Slag A	-0.31	-1.00	1.58	0.41
KYS120 Slag B	0.10	-1.10	0.25	-0.31

Table T.2 Loading vector values

Original Variables	Loading Vectors			
	1	2	3	4
MgO	.42	.13	.71	-.13
Al2O3	.66	-.52	.11	-.13
SiO2	-.57	-.40	.39	.43
P2O5	.86	.33	.02	-.04
K2O	.50	.46	.60	-.13
CaO	.46	-.61	.50	.14
TiO2	-.53	.03	.48	.24
V2O5	-.04	.83	.29	-.26
Cr2O3	.70	.09	.04	-.59
MnO	.86	-.30	-.19	-.04
FeO	-.54	.64	-.38	-.22
Co3O4	-.85	.05	-.31	.06
CuO	.69	.28	-.23	.06
ZnO	.52	.37	-.38	.36
SeO2	.37	.83	.13	.06
SrO	.78	.08	-.12	.38
Y2O3	.92	-.05	-.07	.26
ZrO2	.90	.12	.03	.17
BaO	.55	-.66	-.18	-.29
La2O3	.61	.62	-.02	.33
CeO2	.82	-.15	-.04	.00
Nd2O3	.78	-.34	-.23	-.08

Table T.3 Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.75	44.33	44.33	9.75	44.33	44.33
2	4.23	19.24	63.57	4.23	19.24	63.57
3	2.20	10.01	73.58	2.20	10.01	73.58
4	1.35	6.15	79.73	1.35	6.15	79.73
5	1.00	4.53	84.26			
6	.71	3.21	87.47			
7	.59	2.67	90.14			
8	.44	2.01	92.16			
9	.36	1.62	93.78			
10	.32	1.44	95.22			
11	.29	1.32	96.54			
12	.26	1.18	97.71			
13	.16	.73	98.44			
14	.10	.43	98.88			
15	.08	.35	99.22			
16	.06	.26	99.48			
17	.05	.23	99.71			
18	.03	.14	99.85			
19	.02	.08	99.93			
20	.01	.05	99.98			
21	.00	.02	100.00			
22	.00	.00	100.00			